CANADIAN GOVERNMENT

R & D ORGANIZATIONS

IN BRITISH COLUMBIA

A Survey Conducted for the Premier's Advisory Council
on Science and Technology
by
STC Enterprises
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EXECUTIVE SUMMARY

This report contains the results of a survey of the seventeen research organizations from seven Federal government departments and agencies with visible research and development activities in British Columbia. It does not include information on Federal funding of research and development through grants and contracts (other than by the seventeen organizations mentioned above).

Most readers who get beyond the Executive Summary will want to read the first three chapters only. Later chapters contain much more detailed information for each of the seven departments and agencies. On the other hand, those wishing information about a specific research activity may prefer to skim the first three chapters and proceed directly to the relevant chapter in the latter part of the report.

In the fiscal year 1991/92, the seven departments and agencies spent approximately $100 million at their seventeen research facilities in B.C. It is estimated that approximately 75% of this sum was for Research and Development activities proper as defined by Statistics Canada, with the remainder being "Related Scientific Activities" such as hydrographic surveys. The seventeen organizations combined employed some 338 scientists and a total of 1137 employees in 1991/92. Employment levels on average appear to have been fairly stable over the past five years, with the exception of Agriculture Canada which has seen a gradual decline in size, accompanied by the closure or virtual closure of two establishments.

According to Statistics Canada, 5.9% of Federal internal R&D expenditures are made in B.C. (B.C. has approximately 11.5% of the Canadian population.) Approximately 45% of Federal internal R&D expenditures are made in the National Capital Region in the environs of Ottawa and Hull.

Fisheries and Oceans Canada (DFO) is by far the largest operator of Federal R&D establishments in B.C. with almost 36% of the $100 million total Federal expenditures in B.C. in 1991/92. DFO operates two major facilities, the Pacific Biological Station at Nanaimo and the Institute of Ocean Sciences near Sidney, and two small ones in West Vancouver and at Cultus Lake. Other departments and agencies with substantial operations in B.C. listed in declining order of expenditures are: Agriculture (15.7%), National Defence (14.1%), Forestry (14.0%), Energy, Mines and Resources (9.0%), the National Research Council (8.5%) and Environment Canada (2.9%).

The regional distribution of Federal research facilities in B.C. is heavily focused in the Victoria region (52%), with Nanaimo in second place at 21%, followed by Vancouver (13%), the Okanagan Valley (8.6%), the upper Fraser Valley (over 3%), Kamloops (over 2%), and small facilities at Prince George and Creston.

The extent of the research and of the industrial contacts and support which it generates is too broad to mention in an Executive Summary. Brief summaries appear in Chapters 2 and 3, with much more detail on individual programs in the following chapters.

The review of industrial support by the research organizations was particularly striking in that the very strong role of the now defunct Unsolicited Proposal (UP) Program showed through almost everywhere. While no quantitative measure is provided, it seems almost certain that the combination of the end of the UP program and severely reduced research facility operating budgets has crippled, or, at the least, very severely attenuated, what was an effective technology transfer and support activity a few years ago. The advent of the recently announced Green Plan should help to remedy this situation, but only for activities relevant to environmental protection.

ACKNOWLEDGEMENT

We would like to thank all those who worked to contribute information to this report. For the most part, these are the directors, scientists and staff members of the Federal research facilities visited. Much of the information and many of the words (particularly those in Chapters 4-10) flowed directly from their pens.

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CHAPTER 1 - INTRODUCTION

This report contains summarized information on known R&D activities being undertaken by Federal government departments and agencies in British Columbia. It does not include Federal extramural support of R&D, except insofar as this results directly from intramural R&D activities. For example, a contract by the Atmospheric Environment Service to develop a special purpose work station is included, whereas NRC funding of TRIUMF and IRAP, various Department of Industry, Science and Technology industry support programs, and NSERC university research program expenditures are not included.

The report is the result of a contract from the Secretariat of the **Premier's Advisory Council on Science and Technology** (PACST). The premise on which the contract was let is that the Federal R&D presence in B.C. is a strong and constructive one, and that any policies or programs which B.C. may choose to develop should be determined with a clear understanding of the nature and extent of federal government R&D activities in B.C. The information collection work on which this report is based took place during the first quarter of 1992.

In a project of this nature, it would be easy to spend a lot of effort and money putting together a very comprehensive survey of what is a very substantial (over $100 million p.a.) R&D presence in the province. This was not the approach taken. Rather, the course chosen was to restrict the effort to a point where there was a reasonable assurance of obtaining a good overview, but with a limited opportunity to follow up where detail was lacking. Thus, the reader should expect to find good summary information in this report, but should also expect that the level of detail included for different departments varies fairly substantially from one department to the next. In most cases, departments provided printed material which described their facilities and programs, and in some cases, published papers were also provided. This material has been listed and described in the detailed reports on each department. The printed material itself is lodged in the PACST library.

Almost without exception, those in charge of the research laboratories were welcoming and co-operative. Some exhibited a pride in their facility and in its accomplishments which was a real pleasure to experience. We are grateful for the considerable effort to which those interviewed went to respond to our requests.

The procedure followed in collecting the information contained herein was as follows:

1. A list of Federal research facilities in B.C. was prepared based on the *Directory of Research And Development Laboratories/Facilities in Canada* of March, 1990 and published by Industry, Science and Technology Canada in Ottawa.

2. The heads of most of these facilities[1] were contacted, and a meeting was arranged. Prior to the meeting, a set of questions based on the information requested by PACST was faxed to the individual contacted. (A list of the names and addresses of the persons contacted and a copy of the set of questions are attached as Appendices 1 and 2 respectively.)

3. Following the meeting, a brief facility overview was prepared, and the answers to the questions asked were inserted into the questionnaire where these had been provided.

4. The completed draft write-up was faxed back to the person interviewed (normally the Director of the facility) for review and comment. These comments were edited and incorporated into the final text.

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[1] There were three exceptions as follows:

1. The Agriculture Canada Experimental Farm at Prince George now has no resident scientists and is managed from the Kamloops Research Station. Information on this farm is included with information on Kamloops;

2. Responsibility for management of R&D in the Conservation and Protection Branch (Yukon and Pacific Region) of Environment Canada has been given to Dr. Martell of the Canadian Wildlife Service. Thus the Inland Waters Directorate of the department directed our enquiry to Dr. Martell; and

3. The West Vancouver Laboratories of the Department of Fisheries and Oceans (and its associated Cultus Lake Laboratories) are managed by the Director of the Pacific Biological Station in Nanaimo and were not visited separately.

5. A search of available relevant statistical information was also undertaken in order to provide some baseline statistical data.

6. In addition, there were a few telephone interviews and meetings with industrial and academic representatives who had an important association with one or more of the research facilities.

This report is designed in a layered fashion to provide increased level of detail with each layer, starting with the Executive Summary, moving to the overview chapter (Chapters 2), then to the collected summary descriptions of each research facility (which have been assembled in Chapter 3), and thence to the succeeding chapters which treat the research organizations of the departments in fair detail. (Substantial fractions of the Overview at the start of each chapter are repeats of the departmental summaries in Chapter 3 to enable readers interested in only one research topic to skip Chapter 3 and move directly to the appropriate department-specific chapter).

Should the reader wish to obtain more information than is found in this report, he or she can scan the descriptions of additional information stored in the PACST library (to be found as a part of item 10 of the questionnaire responses for each research facility) to determine whether a visit to that source will suffice, or alternatively, the facility in question can be contacted using the names, addresses and telephone numbers provided.

As is normal when an endeavour such as this is undertaken for the first time, the effort which individual organizations put into responding to the questions varied substantially from one organization to the next. It would be reasonable to expect that if the exercise were to be repeated a greater degree of uniformity of detail in the responses would be achieved, since the heads of the research organizations would have had the opportunity to view the responses of their colleagues.

The reportage in the ensuing chapters is a mixture of writing by the consultants, text supplied by those interviewed and text which has been shamelessly purloined from various brochures and reports supplied

by the heads of the research organizations interviewed. In general source attributions have not been made in such cases.

In a work of this magnitude, which was accomplished in a few months by one person and an assistant, it is inevitable that some errors will have crept in. It is our hope and expectation that the errors are minor, and that they will not seriously undermine the value of the report.

CHAPTER 2 - OVERVIEW

In this chapter, a general overview of Federal intramural R&D in B.C. is presented, including statistical data and comparisons.

2.1 Federal Intramural Expenditures in B.C.

A total of seventeen Federal R&D facilities associated with seven government departments were contacted. The organizations ranged in size from the Pacific Biological Station near Nanaimo, with approximately 230 employees to the Agriculture Canada Kamloops Research Station with 37 employees, to the Vancouver office of the Atmospheric Environment Service which has no formal R&D organization, but which nonetheless has the equivalent of about 7 person years of professional meteorologist time devoted to development, some of which has led to valuable new products for B.C. industry.

As can be seen from Table 2.1 on the next page, the Federal government spent about $100 million at these facilities in 1991-92. Federal expenditures on R&D have been roughly constant in constant dollars since 1984 (see figure 2.1 on page 6). However this figure is a little misleading, since on average, (in constant dollars), extramural funding of R&D has risen, while intramural funding of R&D has declined in response to political pressures which have been calling for greater support for science outside of government.. Where the figures were available, actual budgets and manpower have been provided in the detailed descriptions in the later chapters for the past five years or so for the research facilities visited. With the exception of the Department of Agriculture, which has closed down some research establishments and redistributed part of the manpower amongst the remaining establishments, the Federal R&D organizations in B.C. seem to have had a reasonable measure of stability over the past few years. (In the 1984 to 1989 time period, funding for Agriculture Canada R&D declined by an average 2.9% p.a. across Canada unadjusted for inflation.) Some of this apparent stability is due to the fact that while the "A-base" resources and

manpower declined, the deficit was at least partly compensated for by a variety of "temporary" targeted programs such as the Green Plan and the Federal Provincial Forest Resource Development Agreement (FRDA). As one observer remarked, the result appears to be a shift in emphasis towards near term projects and programs. Some fear was expressed that this could lead to a loss of first class scientists to the universities and abroad.

Department	Gross Expenditures ($K)	Scientists (person years)	Total (person years)
Agriculture (15.7% of Total)	**$15,879**	**65.75**	**232.0**
Agassiz Research Station	$3,288	15.75	57.5
Kamloops Research Station (incl. Prince George)	$2,233	6	32
Summerland Research Station	$6,079	24	86
Vancouver Research Station	$4,279	20	56.5
Energy, Mines & Resources (9.0% of Total)	**$9,039**	**49**	**90**
Pacific Geoscience Centre (Sidney)	$5,123	16	42
Cordilleran Division (Vancouver)	$3,916	33	48
Environment (2.9% of Total)	**$2,920**	**12**	**35**
Canadian Wildlife Service (Delta)	$1,520	12	18
Environmental Protection (West Van)	$600	0	10
Atmospheric Environment Service (Van)	$800	0	7
Fisheries & Oceans (35.8% of Total)	**$36,073**	**83**	**404.8**
Biological Sciences (Nanaimo)	$20,820	47	185.1
Biological Sciences (West Van., Cultus Lk.)	incl.	incl.	50
Institute of Ocean Sciences (Sidney)	$15,253	36	169.7
Forestry (14.0% of Total)	**$14,120**	**47**	**148**
Pacific Forestry Centre (Victoria & Prince George)	$14,120	47	148
National Defence (14.1% of Total)	**$14,207**	**50**	**130**
Defence Research Est., Pacific (Victoria)	$14,207	50	130
National Research Council (8.5% of Total)	**$8,611**	**31**	**97**
Dominion Astrophysical Observatory (Victoria)	$3,750	14	41
Dom. Radio Astrophysical Obs. (Penticton)	$2,636	7	28
Engineering Laboratories (Vancouver)	$2,225	10	28
Total	**$100,849**	**338**	**1137**

Source: Questionnaires. Agriculture Canada (Vancouver) figures are for 1990/91. Environment Canada data for the Atmospheric Environment Service and Environmental Protection are approximate.

Table 2.1 - Federal Intramural Scientific Expenditures and Person Years in B.C., 1991/92

There has also been a certain amount of re-organization taking place in Ottawa, which has led to some apparently anomalous results if

only the R&D statistics are examined without an awareness of what is behind them. For example the Pacific Forestry Centre has been in operation in Victoria since 1965, but over the years it has variously been a part of many different departments, including Environment Canada and Agriculture Canada in recent times. The Institute of Ocean Sciences has also had a history of drifting (or being navigated?) between departments, having also been a part of Environment Canada before being moved to Fisheries and Oceans.

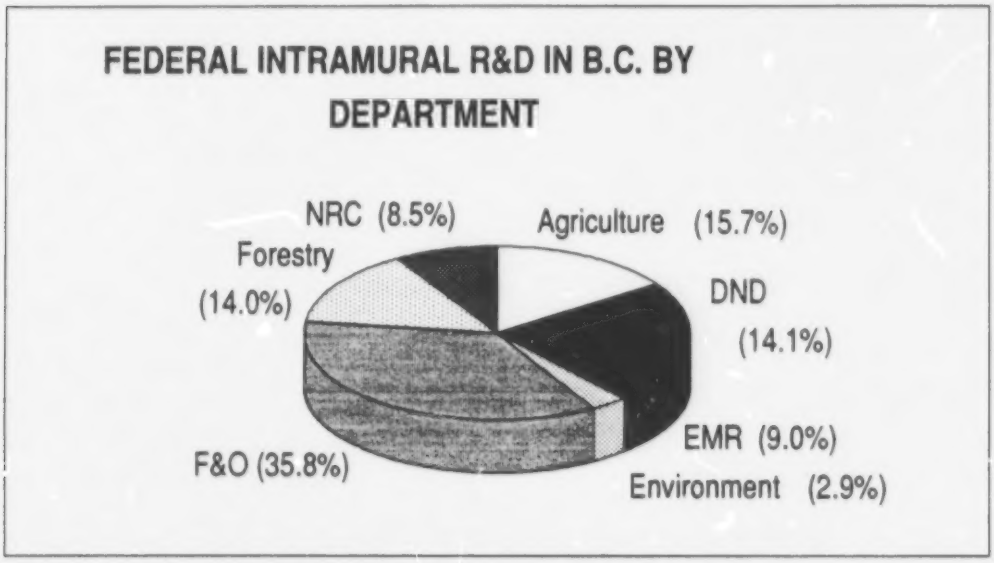

Figure 2.1 - Federal Intramural Scientific Expenditures in B.C., 1991/92

Statistics Canada draws definitional lines between R&D activities and Science and Technology expenditures, with the latter subsuming the former, and including, in addition, a variety of peripheral activities, most notably including scientific data collection.[2] This study was facilities-based, and did not attempt, for example, to extract detailed information as to the proportion of research to scientific data gathering activity. Just as in industry, government has found that it is frequently more effective to have R&D intimately involved in operational roles than to draw clear organizational lines which all too easily lead to physical and intellectual separation. Thus we find that the chief occupation of the Hydrography

[2]See Appendix 3 for a discussion of the relevant definitions.

group at the Institute of Ocean Sciences is producing charts, tide tables and other aids to navigation. However there are 15 research scientists in the group who are busy with such tasks as new instrumentation for surface current studies, multibeam echo sounder trials, under ice acoustic sounders and hydrography software development. Likewise, the task of collecting data on the size of fish populations and the amount of pollutants present is a large one, and important both for operational and research reasons. Some of this data collection is carried out by employees and contractors of the Pacific Biological Station. Some indication of the mix between scientific data collection, research and participation in operational matters will be found in the detailed chapters on each department, but an authoritative division of activities is beyond the scope of this work. However, based on a comparison of Statistics Canada's figures and our own, we estimate that about 75% of the total $100.8 million expenditures in 1991/92 by the facilities we reviewed were for "R&D" under the StatsCan definition, with the remainder devoted to "Related Scientific Activities".

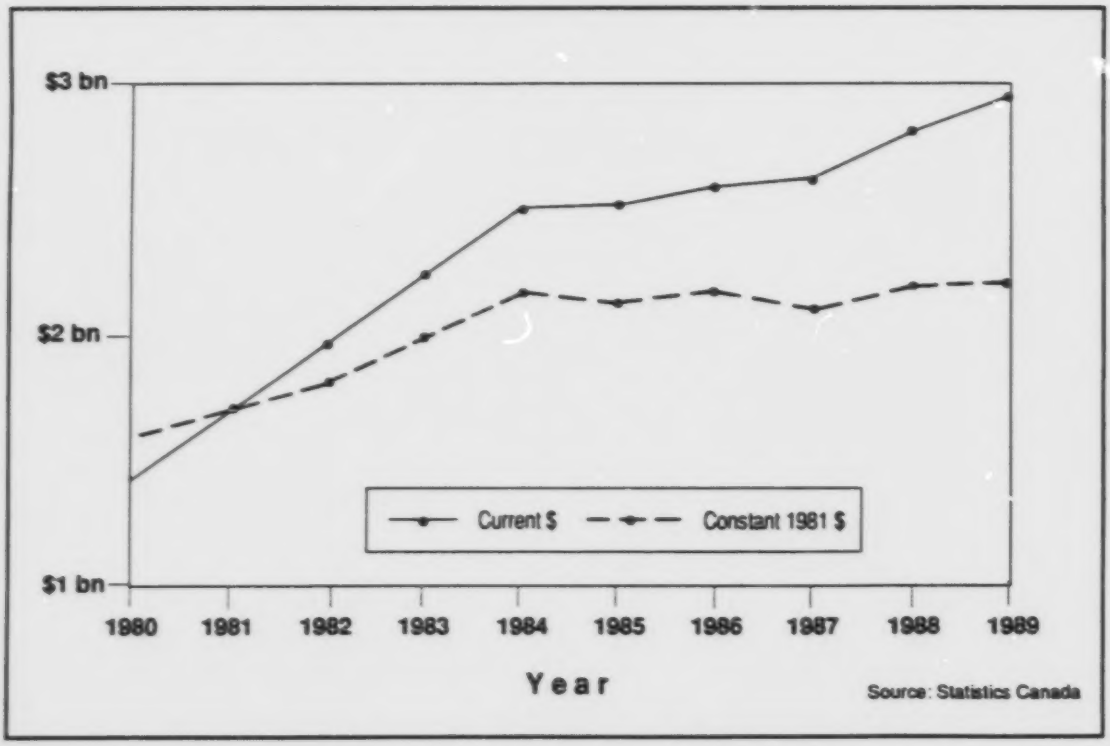

Figure 2.2 Federal R&D Expenditures 1980/81 to 1989/90

Several interesting facts emerged from the data collected. Those which seem most salient have been set out in ensuing sections.

2.2 Some "Vidious" and Invidious Comparisons

As already stated, over $100 million was spent by Federal departments in B.C. on R&D and closely related scientific activities in 1991/92. For comparison purposes, some other R&D expenditures in B.C. have been shown in Figure 2.3. As can be seen, Federal intramural expenditures are somewhat less than the $120 million in research grants received by U.B.C. in 1991/92, slightly more than the projected operating costs for the proposed KAON particle physics facility ($95 million), and somewhat more than the annual budget of approximately $60 million of MPR Teltech, the B.C. Government intramural research budget of $17.1 million and the total B.C. Government R&D expenditures in 1990/91 of $64.6 million.

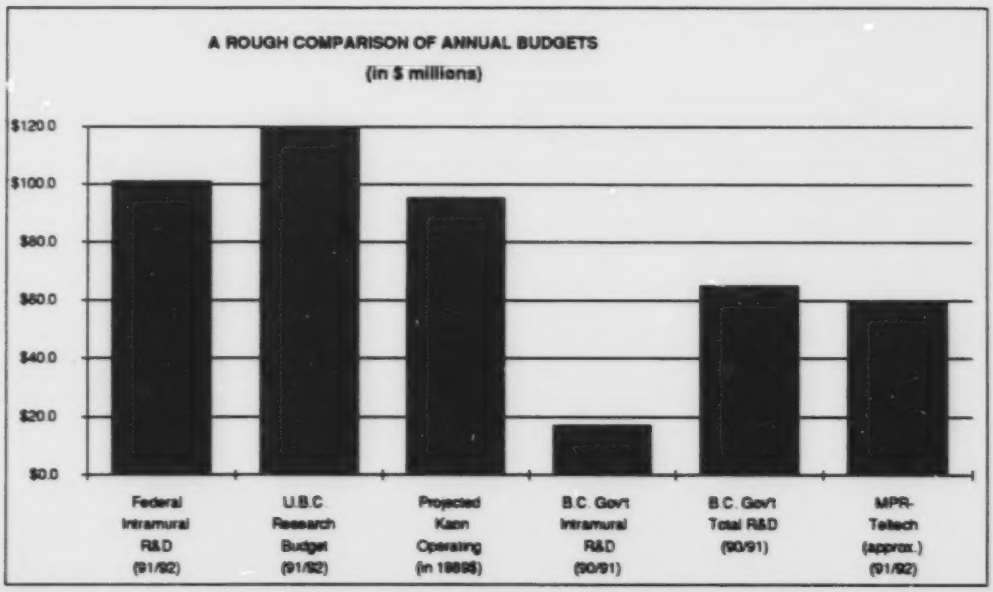

Figure 2.3 - A Rough Comparison of Some Annual R&D Budgets in B.C.

According to Statistics Canada, Federal government intramural expenditures in B.C. are 5.9% of the total of such expenditures in Canada. Since B.C.'s share of the population of Canada is currently about 11.5%, this gives some credence to a popular view that the west in general, and B.C. in particular, is shortchanged by Ottawa insofar as

general, and B.C. in particular, is shortchanged by Ottawa insofar as such research activities are concerned. Looking more broadly at Federal expenditures on all R&D (i.e. including funding to universities, industry and others), B.C.'s share rises to 8.4%, which is still short of a "fair" distribution. It is worth noting that a very large fraction of Federal intramural R&D (44.9%) is performed at Headquarters, i.e. in the National Capital Region. This phenomenon is clearly evident in Figure 2.4, which shows per capita expenditures by province. A somewhat surprising fact, which this chart demonstrates clearly, is the very small amount of R&D which takes place on the Quebec side of the National Capital Region. In fact, the expenditure is so small ($1.7 million), that it is almost undetectable in figure 2.4. The Canadian average per capita expenditures on intramural R&D was $44.63 in 1986. As can be seen from the figure, this average expenditure was exceeded by Nova Scotia ($76.59), Ontario ($69.24), Manitoba ($65.36), P.E.I. ($55.43) and Newfoundland ($47.00). The detailed numbers from which these figures were taken are shown in Table 2.2. The heavy weighting of Federal expenditures in the National Capital Region shows at the bottom of the table at $579.31! It is interesting to note that if a similar calculation is performed for Federal R&D expenditures in Greater Victoria, the figure comes to $175.44.[3] We did not calculate the corresponding figure for B.C. government intramural research in the Victoria region.

2.3 Comments on the Impact of the Research

It is very difficult to assess the direct impact of all these scientific activities on the B.C. community, but it has undoubtedly been major. Our visits to the research facilities uncovered a virtual treasure trove of important and interesting work. This work has been explained in greater depth in the departmental summaries in the next chapter, and in the subsequent chapters containing detailed information. In this section,

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[3] This number was calculated using the very rough R&D expenditure figures (which include some "Related Scientific Expenditures") collected during this study. The population of Greater Victoria (including Esquimalt and the Saanich peninsula) was taken to be 298,974. Federal intramural research expenditures in the Greater Victoria Region were $52.5 million in 1991/92.

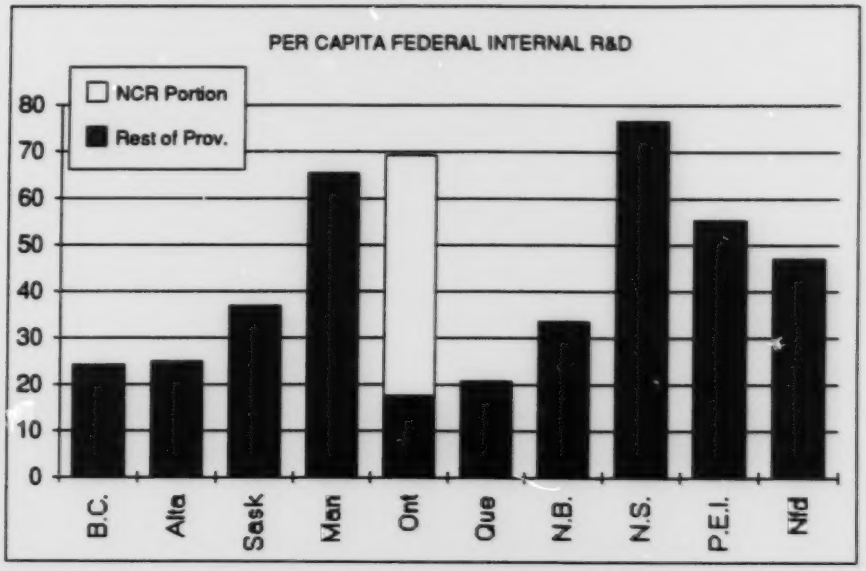

Figure 2.4 - Per Capita Federal Intramural R&D Expenditures by province, 1988/89

1. As a result of research at the Pacific Biological Station (and similar work in New Zealand and California), it is possible to analyse the scales of a salmon caught at large in the Pacific and from the results of the analysis, to determine which river system (and sometimes even which spawning bed) it was borne in. This capability is critical to international salmon fishery negotiations. The research station has also been heavily involved for many years in research on the effects of drift net fishing. Results of this research have been an important factor in international agreements banning such activities in the North Pacific.

2. By studying the interaction of rail wheels on steel rails, the Engineering research group of NRC has developed a preventative maintenance strategy which is estimated to save Canadian

	Population (in thousands)	Percent of Total Population	Intramural NSE R&D Spending (in $ thousands)	Percent of Total Spending	Per Capita Spending
British Columbia	2,984.0	11.5%	$ 72,300	5.9%	$24.23
Alberta	2,401.1	9.3%	60,000	4.9%	$24.99
Saskatchewan	1,011.2	3.9%	37,200	3.0%	$36.79
Manitoba	1,084.7	4.2%	70,900	5.8%	$65.36
Ontario (inc. NCR)	9,430.8	36.4%	653,000	58.3%	$69.24
Ontario NCR	*9,430.8*	*36.4%*	*487,500*	*44.4%*	*$51.69*
Quebec (inc. NCR)	6,639.2	25.6%	137,700	11.7%	$20.74
Quebec NCR	*6,639.2*	*25.6%*	*1,700*	*0.5%*	*$0.26*
New Brunswick	714.4	2.8%	23,900	2.0%	$33.45
Nova Scotia	883.9	3.4%	67,700	5.6%	$76.59
Prince Edward Island	128.1	0.5%	7,100	0.6%	$55.43
Newfoundland	568.1	2.2%	26,700	2.2%	$47.00
Canada	**25,923.3**	**100%**	**$1,156,900**	**100%**	**$44.63**
Ottawa/Hull metropolitan area	*844.6*	*3.3%*	*$489,200*	*42.3%*	*$579.21*

Population estimated from 1986 census as at June 1, 1988, in thousands. Source : StatsCan 91-200

1988/89 intramural NSE R&D expenditures source: StatsCan 22-204

Table 2.2 - Federal Intramural Spending on R&D by province, 1988/89

railways about $100 million annually. The system is now in use in other countries as well. The same group has played a key role in reducing the rail-wear-induced noise of the Skytrain.

3. The Cordilleran Division of the Geological Survey of Canada has just released a large scale geological map of the Canadian Cordillera (i.e. most of B.C.) which is the culmination of ten years of work. It is believed to be one of the best of its kind to be found anywhere, and is an invaluable tool for geologists searching for new mineral finds in the province.

4. The Vancouver Research Station of Agriculture Canada is working on the development of techniques to alter genes in a plant to give it better resistance to certain viruses. The same station has also

developed new rapid and inexpensive ways to diagnose viral and other infestations through analysis at the cellular and molecular levels.

5. The Vancouver office of the Atmospheric Environment Services, facing a lack of information on meteorological conditions over the Pacific Ocean, (which happens to be where most of B.C.'s weather comes from), has become expert at interpretation of satellite data, and has developed new techniques to improve the ability to forecast rapidly developing intense storms off the West Coast, with resulting improvements in safety for fishermen and others. This same knowledge has also been used to help B.C. industry develop new and successful data analysis and display products.

6. Astronomers at the Dominion Astrophysical Observatory in Victoria have analysed data from the Hubble Space Telescope to uncover a site of extraordinary star formation which began only three million years ago.

7. Research at the West Vancouver Laboratories of the Department of Fisheries and Oceans has resulted in the development of simple techniques to ensure that all Chinook salmonid for use in aquaculture are female (females are larger and all mature at the same time). This same technique has now been applied to Japanese scallops.

8. Path breaking work on Blue Herons by scientists at the Canadian Wildlife Services Centre in the Fraser delta uncovered the increasing amounts of dioxins in B.C. waters, and led directly to dioxin investigations by the Department of Fisheries and Oceans, which in turn led to some fisheries closures.

9. Defence research in Esquimalt directed towards under ice surveillance is an important component in the maintenance of Canadian sovereignty in the Arctic.

10. A group of scientists at the Institute of Ocean Sciences is involved in large international co-operative projects aimed at gaining a better understanding of large scale ocean circulation. These studies have important implications for our understanding of fish migration and of weather patterns.

11. A variety of cultivars of strawberries, raspberries, apples, cherries and other fruits have been developed at the Vancouver and Summerland Agricultural Research Stations and successfully introduced commercially. The rapidly growing greenhouse vegetable industry in B.C. owes much to the hydroponic research at the Agassiz Research Station, while the Vancouver Research Station has played a major role in the virus free seed potato industry in the Pemberton area. Research in integrated pest management and virus chemistry are helping to drive important changes in our approach to the use of chemicals in agriculture.

12. Scientists at the Pacific Geoscience Centre are playing an important role in exploring and understanding the mineral deposition taking place at undersea spreading ridges. This work has important implications for understanding the mineralization that took place millions of years ago in B.C.'s Cordilleran Range. Other scientists at the same centre continuously monitor earthquakes, and seek better methods for predicting the occurrence of disastrous events of this kind.

13. Research at the Pacific Forestry Centre in Victoria has led to functional pest management systems for Douglas-fir beetle, Douglas-fir tussock moth, Douglas-fir seed orchard pests. As well, a population model for the mountain pine beetle has been developed and put to use.

2.4 Comments on the Industrial Benefits

It was frustratingly difficult to get hard information on the industrial benefits arising from the research. Some of the following examples may help to shed a little light on the subject:

- Both the Defence Research Establishment, Pacific and the Institute of Ocean Sciences have worked with International Submarine Engineering Research Ltd. (ISER) of Port Coquitlam in the development of autonomous (unmanned) underwater vehicles. Heavy initial use was made of the now defunct Unsolicited Proposal fund administered by the Department of Supply and Services. It is believed that the future market for such vehicles will be in the hundreds of millions of dollars, and ISER currently is the world leader in this technology.

- In addition to its work with ISER, the hydrographers at the Institute of Ocean Science have directly spawned three companies through spin-offs, the Axys Group (formerly Seakem) based in Sidney, which now employs over 110 people and has sales of over $10 million; Arctic Sciences also of Sidney, with 10-15 employees, and which offers consulting expertise in Arctic Physics; and Questar Tangent which has annual sales of about $1 million and produces integrated systems for automated hydrography. In addition, the hydrography group has been a lead client and co-developer of a laser surveying device which has brought Terra Surveys important contracts in Indonesia and with the U.S. Army Corps, while Applied Microsystems Ltd. of Sidney employs about 15 persons in the manufacture of instrumentation, much of it under license from IOS. However, since the end of the Unsolicited Proposal Fund, and more generally with the budget cutbacks in recent years, activities leading to new commercial products appear to have been greatly attenuated.

- The Atmospheric Environment Service has no research scientists in B.C., nor does it have a formal research program. It does,

however, become involved in a lot of development, and estimates that on average the equivalent of seven person years are devoted to such activities, much of it with contractors. MacDonald Dettweiler and Associates, again with generous assistance from the Unsolicited Proposal Fund, have been major beneficiaries of AES's initiatives in the realm of weather information transmission systems (their Metdas system has been adopted in a number of countries), and development work is now in progress on a new work station for weather interpretation.

- Both of our astrophysical observatories (at Victoria and Penticton) have worked with Coast Steel Fabricators Ltd. of Port Coquitlam: Victoria regarding a contract to build the enclosure for the Canada France Hawaii Telescope (CFHT), and Penticton regarding the design of a novel antenna system in connection with the proposed Schmidt Radio Telescope. As a direct result, Coast Steel has become the leading producer of astronomical enclosures, including a recently completed $8 million contract for the Keck Telescope enclosure, which is the world's largest. Overall, Coast Steel believe that the introduction to astronomy given them by their work on CFHT has led to about $70 million in contracts over the past 15 years. The association with DRAO in Penticton is much more recent, but has already led to about $1 million in contracts with Caltech and the Smithsonian, which they hope is but the beginning of another new line of business in high accuracy sub-millimetre antenna arrays.

- Quite apart from the benefits to farmers arising from the research at the various Agriculture Canada Research Stations in B.C., there are a host of small companies (and some large ones) which have taken up manufacture and supply of Agrican developments. These include Applied Bionomics, PheroTech, Turbomist, Agriforest Nurseries, Integrated Crop Management, the Okanagan-Kootenay Sterile Insect Release Board, and the B.C. Fruit Growers.

- The Pacific Forestry Centre played a major role in the launch of Safer as a successful supplier of pesticide chemicals which currently employs about 65 people, 27 of whom are in the R&D department. In addition, PFC research into forest fire prevention led directly to the founding of FTS Ltd. in Victoria, which manufactures and markets an automatic remote fire weather station that was initially developed by the PFC. There are now over 1000 such systems in use in Canada alone, and sales in the U.S. and Australia are under way.

- Barrodale Computing of Victoria had its beginnings in a series of contracts with the Defence Research Establishment, Pacific, and recently obtained a sizable contract to help IBM convert the computer software at the Dominion Radio Astrophysical Laboratory in Penticton from a competitor's machine to IBM. Now IBM Canada have started to market the software, and it is expected that they will soon be joined by IBM U.S. and IBM U.K. This could be a major breakthrough to this 12 person company .

- The City of Kelowna worked with Environment Canada (again using Unsolicited Proposal funds) to develop a biological sewage treatment system called BIO-P. The new system saved the city over $30 million, and has been adopted by a number of other cities in B.C. and elsewhere. A U.B.C. professor provided many of the ideas behind the system, and two firms of consultants are busy planning new installations in cities around the world.

All those interviewed as a part of this undertaking were asked if they had any suggestions as to what PACST and/or the B.C. government could do to help make Federal intramural research more beneficial for British Columbians. In the light of the evidence above, it is perhaps not surprising that there were a number of requests that the province should endeavour to help convince the Federal government to re-initiate the modest, but apparently very effective, Unsolicited Proposal program.

2.5 Regional Distribution of Expenditures within B.C.

It may come as a surprise to some readers to learn how much of Federal government intramural research spending in B.C. is concentrated in Southern Vancouver Island. Over $52 million of the $101 million total was spent in the Greater Victoria Regional District alone. If the Pacific Biological Station at Nanaimo is included in a larger "Southern Vancouver Island" district, the figure rises to over $70 million! The distribution of Federal intramural R&D expenditures over the province is shown in Figures 2.5 and 2.6. Table 2.3 is a recasting of Table 2.1 to show activity by region rather than by department. Where possible manpower and budgets for subsidiary stations (such as Prince George and Cultus Lake) have been broken out from their parent budgets, but accurate data is missing in most cases.

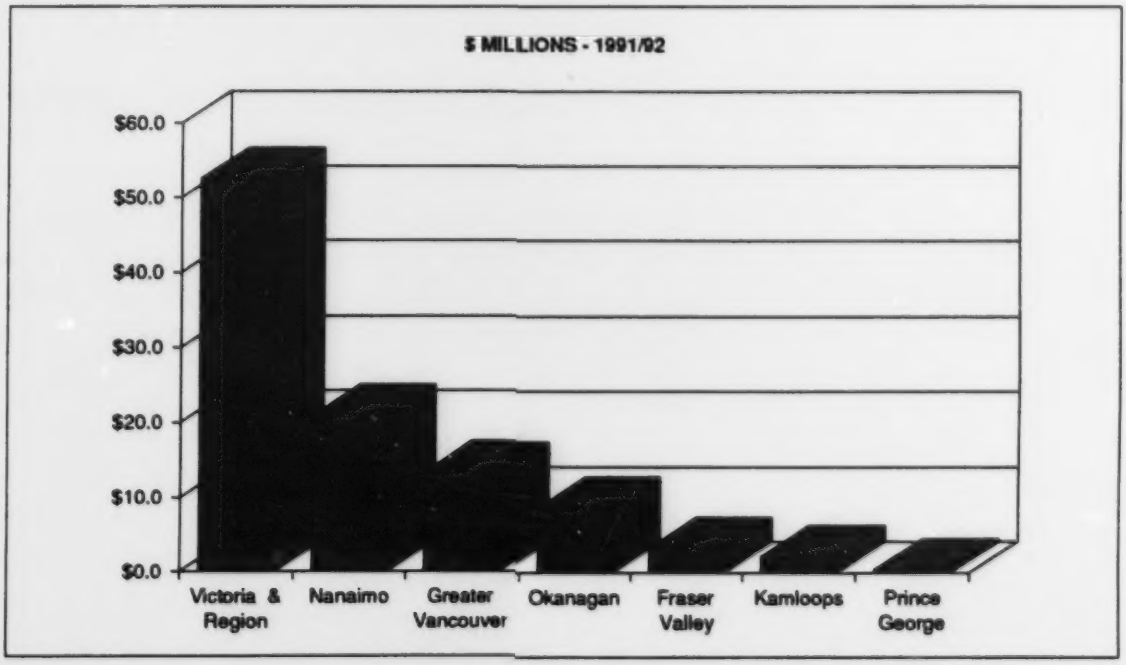

Figure 2.5 - Regional Distribution of Federal Intramural Expenditures in B.C.

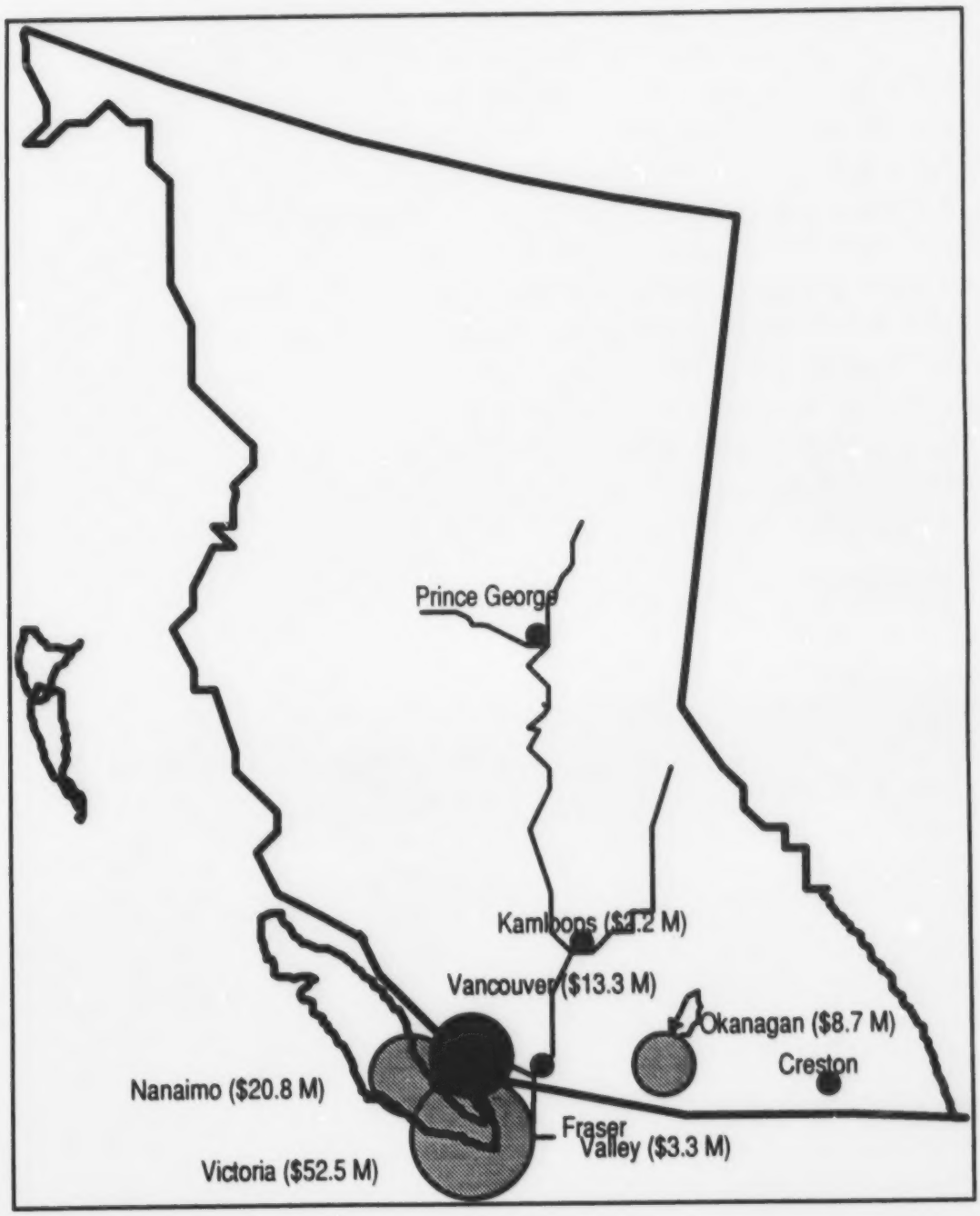

Figure 2.6 - Location of Principal Federal Research Establishments in B.C.

2.6 A Note on Tradition

In an age where most institutions, perhaps particularly scientific ones, seem to be undergoing constant creation and dissolution, some readers may be surprised to learn that some of our Federal research institutions in B.C. date back to very early days in the history of the province. The Geological Survey of Canada was active in B.C. in 1877, and has been in existence since 1842, making this year its 150th anniversary. The Agricultural Research Station at Agassiz was one of the original five research stations established in Canada in 1886 under the terms of the Experimental Farm Act. Some of the other Agricultural Research Stations also go back a fair distance in time, Summerland to 1914, and Kamloops to 1928. The Pacific Biological Station at Nanaimo was founded by a retired Anglican clergyman in 1908. A part of this story has been well captured on a recent videotape about the station filed in the PACST library.

All this history need not be a sign of excellence. Indeed, it could be interpreted as a sign of ossification. Our impression was that, to the contrary, the laboratory directors concerned viewed the history of their institutions with pride and a sense of responsibility for the maintenance of a noble tradition. Change there has certainly been, but for the most part it has taken place as a necessary part of maintaining the tradition. More than one director pointed to other countries where those in power had brought about violent change to sister research institutions with a similar proud history, and found that the cure was much worse than the disease. Countries specifically mentioned in this category were the U.S., the U.K. and New Zealand. While the value of tradition can easily be exaggerated, perhaps especially in an institution devoted to research, it seemed to us that for the most part the sense of tradition was constructive, and a credit to all concerned, especially the politicians who refrained from the temptation to make radical changes. Life has been far from a bed of roses for federal research scientists in B.C. as elsewhere, and some would doubtless claim that they are suffering a slow death by a thousand cuts, but, with a few exceptions, the institutions themselves

have remained more or less intact, and have continued with what appears to be a productive existence.

Region/Facility	Gross Expenditures ($K)	Scientists (person years)	Total (person years)
Greater Victoria	**$52,453**	**162**	**528**
Defence Research Est., Pacific, DND	$14,207	50	130
Pacific Geoscience Centre, EMR	$5,123	16	42
Institute of Ocean Sciences (Sidney), DFO	$15,253	36	170
Pacific Forestry Centre (Victoria), For. Can.	$14,120	46	145
Dominion Astrophysical Observatory, NRC	$3,750	14	41
Nanaimo	**$20,820**	**47**	**185**
Pacific Biological Station, DFO	$20,820	47	185
Greater Vancouver	**$13,340**	**75**	**208**
Vancouver Research Station, Ag. Can.	$4,279	20	56.5
Cordilleran Division, EMR	$3,916	33	48
Canadian Wildlife Service (Delta), Env. Can.	$1,520	12	18
Environmental Protection, Env. Can.	$600	0	10
Atmospheric Environment Service , Env. Can.	$800	0	7
West Vancouver Lab., DFO	not available	not avail.	40
Engineering Laboratories, NRC	$2,225	10	28
Okanagan Valley	**$8,715**	**31**	**114**
Summerland Research Station, Ag. Can.	$6,079	24	86
Dom. Radio Astrophysical Obs. (Penticton), NRC	$2,636	7	28
Kelowna Exp. Farm (sub. of Summerland)	not available	not avail.	not avail.
Fraser Valley	**$3,288**	**15.75**	**67.5**
Agassiz Research Station, Ag. Can.	$3,288	15.75	57.5
Abbotsford Exp. Farms (2-subs. of Ag. & Van.)	not available	not avail.	not avail.
Cultus Lake Laboratory, DFO	not available	not avail.	10
Kamloops	**$2,233**	**6**	**30**
Kamloops Research Station, Ag. Can.	$2,233	6	30
Prince George	**$0**	**1**	**5**
Forestry Canada	not available	1	3
Prince George Exp. Farm (sub. of Kamloops)	not available	0	2
Kootenay	**$0**	**0**	**0**
Creston Experimental Farm (sub. of Summerland)	n.a.	n.a.	n.a.
Total	**$100,849**	**338**	**1137**

"Not Available" means that time did not permit returning to the departments concerned to seek further detail.
Source: Questionnaires. Agriculture Canada (Vancouver) figures are for 1990/91.

Table 2.3 - Regional Distribution of Federal Government Laboratories in B.C., 1991/92

2.7 A Note on Balance

When Federal R&D expenditures as a percentage of gross revenues from the industry are compared as between B.C. and Canada as a whole (see Table 2.4), the numbers look surprisingly well balanced for agriculture and the fisheries, but rather out of tolerance for forestry and mineral and energy resources. Forestry Canada appears to spend about 2.6% of logging revenues for Canada as a whole, but only about 1% of the corresponding figure for B.C. in B.C. For the Department of Energy, Mines and Resources, there is an apparent discrepancy of about a factor of three. This department has traditionally centralized most of its research facilities in the National Capital Region, so it is likely that all provinces except Ontario experience a similar imbalance.

SECTOR		CANADA			BRITISH COLUMBIA		
		Industry Revenue ($ million)	Federal R&D Spending	R&D as % of Revenue	Industry Revenue ($ million)	Federal R&D Spending	R&D as % of Revenue
Agriculture (1990)	Farm Gate Receipts	$19,656.0	$310.9	1.6%	$1,143.0	$15.9	1.4%
Fishing (1990)	Landed Value	$1,509.3	$129.9	8.6%	$478.2	$36.1	7.5%
	Processed Value	$3,289.3	$129.9	3.9%	$951.5	$36.1	3.8%
Forestry (1987)	Logging	$2,736.0	$70.4	2.6%	$1,454.5	$14.1	1.0%
	Manufacturing	$20,279.1	$70.4	0.3%	$7,085.3	$14.1	0.2%
EMR (1989)	Mining & Quarrying	$21,381.6			$3,343.8		
	Petroleum	$17,098.0			$937.0		
	Hydro	$7,466.7			$1,500.0		
	Total EMR	$45,946.3	$270.4	0.6%	$5,780.8	$9.0	0.2%

Source: Canada Yearbook 1992 , StatsCan 15-203 and StatsCan 66-204, B.C. R&D statistics from this study (See table 2.1). The Federal R&D Spending figures for B.C are for 1991/92 and include some related scientific expenditures. Moreover, the years for the various statistics do not in general match the corresponding Revenue

Table 2.4 - Some Comparisons of Industry Revenue and Federal R&D Spending

CHAPTER 3 - A SUMMARY OF FEDERAL INTRAMURAL R&D ACTIVITIES

3.1 Introductory Comments

This chapter is devoted to brief descriptions of the research activities of each of the seven Federal departments with R&D facilities in B.C. The departments appear in alphabetical order. The chapter is designed for those who do not subsequently wish to read the detailed chapters on each department which follow. If the reader does intend to read the subsequent chapters, then he or she is advised to skip this chapter, since it is largely concocted from the overview sections of each of the following chapters, and is included solely as a convenience for those in a hurry.

3.2 Agriculture Canada

Agriculture Canada currently has four research stations in B.C., the oldest of which is the Agassiz Research Station, which was established in 1886. Agassiz is one of the original five research establishments across Canada started in that year. The other B.C. stations are located in Vancouver, Summerland and Kamloops. The Department is involved in a process of reducing the number of its research stations thereby focussing its research at a smaller number of larger centres. This process is especially difficult in B.C. which has a greater climatic variety than any of the other provinces. In recent years research at the Saanich Station has been closed down (accompanied by an increase in the quarantine functions of the station), and the Prince George Station has been all but closed down, with all of the scientific staff moved elsewhere. Agriculture Canada has recently announced that Kamloops too will lose its independent status, and become a satellite of the Summerland station (all stations operate one or two small farms in areas other than their immediate location).

Historically the farmers of Canada seem to have relied heavily on Agriculture Canada research without themselves making any financial contribution to it. Agriculture Canada is clearly trying hard to close this open feedback loop, but in the current state of the economy generally, and of agriculture in particular, contributions from farm co-operatives are hard to come by. Notwithstanding, they have succeeded in B.C. in obtaining more than 10% of their income from "outside" funding. Although some of this comes

from other government programs, the bulk comes from agricultural co-operatives - some even from co-operatives in the U.S.

The approximate budgets of the four major stations in B.C. and their subsidiary facilities for 1991/92 were as follows:

Facility	Est. Annual Budget($000) Internal Funds	Person Years Scientists	Person Years Total
Agassiz Res. Stn.	$3,288	16	58
Kamloops Res. Stn.	$2,233	6	30
- Prince George Exp. Farm	incl. above	0	2
Summerland Res. Stn.	$6,079	24	86
Vancouver Res. Stn.[1]	$4,279	20	56
TOTAL	**$15,879**	**66**	232

The *Agassiz Research Station* was established in 1886 under the terms of the Experimental Farm Act, and was one of the five original experimental farms in Canada. The station operates two farms in Agassiz covering 665 hectares, and a substation at Abbotsford with 8 hectares.

The research program at the station encompasses both animal and crop sciences. The Animal Science Section focuses on dairy and poultry research, with the former directed towards dairy cattle nutrition, including energy and protein utilization and forage management. The poultry program, operated with the tangible support of the B.C. poultry industry, emphasizes nutrition, physiology and animal behavior. (Some of the research is literally aimed at improving productivity through keeping the hens happier.)

Crop research at Agassiz encompasses management, pre- and post-harvest physiology, entomology and plant pathology of greenhouse and field vegetable crops, plus management of small fruits, including kiwi fruit and hazelnuts. Work on hydroponic growth of greenhouse vegetables seems to hold particular promise. The Agassiz Research Station enjoys close ties with the Faculty of Agriculture at U.B.C.

The *Kamloops Research Station* was established at its present site in 1947, although Agriculture Canada has conducted research in the Kamloops area since 1928. Researchers at the station investigate problems related to the beef cow-calf industry in the interior of B.C. The station also administers the Experimental Farm at Prince George. Researchers at Kamloops develop and transfer technology in the fields of range and pasture management, soil

[1]Data for Vancouver is for 1990/91. Data for 1991/92 was not available.

fertility, plant ecology, poisonous plants, bloat, plant winter hardiness, forage agronomy, quality of conserved forages and ruminant nutrition.

Administration of the Prince George Experimental Farm was transferred to Kamloops from the Research Station at Beaverlodge, Alberta in 1979. There are now no scientists permanently stationed at Prince George. In 1965 consideration was given to closing the Kamloops Station as an austerity measure, however, during a meeting of the B.C. Cattlemen's Association in that year, the then Minister of Agriculture was persuaded to change his mind. On April 1, 1992 the Kamloops Research Station was consolidated with the Summerland Research Station. It remains to be seen whether an active research program will survive in Kamloops.

The *Summerland Research Station* was established in 1914, and is now headquartered in an impressive new office and laboratory complex complete with pilot plant facilities for food research, which was opened in 1987. The building's facilities include a 640 m^2 computer controlled greenhouse with 18 distinct compartments and about 75 controlled environment growth chambers. The station is on a land base of 320 hectares, of which about 90 hectares are irrigated and available for tree fruit and viticulture research. Research on tree fruit production and protection is also conducted at substations in Kelowna and Creston. Effective April 1, 1992 the Kamloops Research Station (and the Prince George Experimental Farm) also became substations of Summerland.

The research program at Summerland is designed to serve primarily the tree fruit and grape industries in the interior of B.C., but many programs have relevance to fruit production and utilization across Canada. Research disciplines represented at Summerland include entomology, plant pathology, food processing, pomology, viticulture, soil science and agricultural engineering. A major program is underway in "integrated pest management", which combines chemical, cultural and biological control methods. The station is proud of its accomplishments in food processing, including the development of "vitaminized" apple juice, a variety of fruit juice blends, and some world class wines.

The *Vancouver Research Station* is the main centre for plant virus research in Canada. In addition, it serves the coastal areas of B.C. on problems of insects and plant diseases in horticultural crops, and the interior of the province on pest problems of vegetables, forages, and potato crops.

Although not formally established until 1960, a laboratory of plant pathology was started in Vancouver in 1946, and other research groups also congregated in Vancouver prior to occupancy of the then-new building on the U.B.C. campus in 1960.

The station is organized into three main research sections, virus chemistry and physiology, plant pathology, and entomology.

Some major accomplishments of the laboratory in recent years include the production of a stable DNA copy of the Cucumber Necrosis virus, preliminary characterization of a baculovirus regulatory gene, successful introduction of the coat protein gene of the potato leafroll virus into Desiree and Burbank potatoes, studies of tuber flea beetles in potatoes, western flower thrips in greenhouse vegetables and aphids on strawberries, various studies connected with raspberries and strawberries, including the introduction of a new cultivars, and the development of serological techniques and monoclonal antibodies for the rapid diagnosis, detection and characterization of plant pathogenic bacteria and viruses.

3.3 Energy Mines And Resources Canada

A comprehensive knowledge of the geoscience of Canada and its vast offshore area is fundamental to environmentally responsible economic development, public safety and national sovereignty. Acquiring, interpreting and making that information available to all Canadians is the mission of the Geological Survey of Canada, and has been since its founding in 1842. The GSC has carried out geological field work in B.C. since 1877.

The GSC has two scientific branches, the Geophysics, Sedimentary and Marine Geoscience Branch (of which the *Pacific Geoscience Centre* outside Victoria is a part), and the Minerals and Continental Geoscience Branch, (of which the *Cordilleran Division* in Vancouver is a part). With minor exceptions, the *Pacific Geoscience Centre* and the *Cordilleran Division* comprise the R&D presence of EMR in B.C.

The approximate size and budgets of the two facilities for 1991/92 were as follows:

Facility	Est. Annual Budget($000) Internal Funds	Person Years Scientists	Person Years Total
Pac. Geo. Ctr.	$5,123	16	42
Cordilleran Div.	$3,916	33	48
TOTAL	**$9,039**	**49**	**90**

The $9 million of scientific expenditures by the department in B.C. 1991/92 compares with overall intramural scientific expenditures by the Department of $341.0 million. This would put the Department's intramural

expenditures in B.C. at approximately 2.7% of their total intramural expenditures.

The *Pacific Geoscience Centre* (PGC) was established in 1978 in a wing of the Institute of Ocean Sciences near Sidney, B.C. Scientists at the centre are involved in broad-ranging geophysical investigations of the Pacific margin, and in monitoring earthquakes and variations in the Earth's magnetic field, mapping of the Earth's gravity field, and measuring the Earth's heat flow.

The Marine Geology Section of the Pacific Geoscience Centre also carries out geological mapping activities to provide geological information to support potential offshore resource evaluation and to contribute to environmental studies. Geoscience survey activity currently being undertaken includes Cordillera bedrock surveys, marine geological studies of Dixon Entrance and parts of the Strait of Georgia, and marine crustal studies of the Juan de Fuca Ridge.

The Environmental Geoscience Program includes installation of seismographic stations in western Canada, analysis of earthquakes in the region, preparation of seismic hazard maps, and studies of the subduction of the Juan de Fuca plate off the west coast of Vancouver Island, and of crustal deformation on Vancouver Island itself.

Many of these studies require ship time which is obtained from the Department of Fisheries and Oceans, and which has been an increasingly scarce commodity in recent years. Four years ago there were 12 to 14 cruises, two years ago there were nine, and last year there were six.

The *Cordilleran Division* sees its role primarily as the provider of the fundamental information about the geology of the Cordilleran Region (comprising most of B.C. and the Yukon, about 10% of Canada's land mass), which those who explore for minerals or energy resources will use to decide where to conduct their search, and which are used by development planners to assess and minimize environmental impacts. These data are further interpreted in terms of hazards to human health and development.

The maps and supporting documents produced by the division are designed to provide a broad scale three dimensional overview of the land and adjacent underwater terrain. It is critical to the success of this endeavour to have an understanding of the changes to the land mass over geological time, hence a major focus of research activity is to determine the age of minerals accurately. The Division has played a leading role in developing techniques for identifying the age of the prevalent sedimentary rock in the region (which dates largely from the Triassic period (260-210 million years ago)), particularly

through the technique of examining the ubiquitous Conodont fossil samples which underwent substantial evolutionary change over the Triassic period.

It is estimated that there are approximately 5000 people in the Vancouver area involved in mineral exploration. These people comprise the primary client base of the research group. The division works closely with its provincial government counterparts in attempting to service their needs. The B.C. and Yukon Chamber of Mines is the primary industry representative group with whom they communicate.

While explorationists are the prime client base for the division, it also has important data on water and rock quality, since, as a part of its ongoing work, it systematically measures the metal content of sediment and water in streams, rivers and lakes. For example, data collected by the division (and made publicly available) was used to determine that the uranium content in the water consumed by residents of Atlin, B.C. was above tolerance levels, and appropriate steps to change the water supply were taken.

The division believes it has played a major role in many of the new exploration initiatives undertaken in B.C. One recent example is activity in the Wolverine complex, which was fostered by theories of the formation of the Caribou plateau developed by researchers in the division. Another example is in Northern B.C.'s Iskut region, where new data on the mineralization determinants indicative of gold occurrences have focussed exploration activity.

3.4 Environment Canada

It is sometimes a little difficult to track the organizational chess which is played by the government, and Environment Canada is surely a case in point. A department of fairly recent origin, it has nonetheless, in its time swallowed and subsequently regurgitated parts of Fisheries and Oceans Canada and all of Forestry Canada. The Canadian Wildlife Service, once an independent entity, is now a part of the Conservation and Protection Branch of the department, the other major operating branches being the Atmospheric Environment Service and the Parks Service.

The approximate budgets of the research activities of the Conservation and Protection (including both CWS and Environmental Protection) and Atmospheric Environment Service branches in B.C. for 1991/92 were as follows:

Facility	Est. Annual Budget($000) Internal Funds	Person Years Scientists	Person Years Total
Cdn. Wildlife Svce.	$1,520	12	18
Env. Protection	$600	0	10
Atmos. Env. Svce.	$800	0	7
TOTAL	**$2,920**	**12**	35

While virtually the only research activity of the department in B.C. is that associated with the Canadian Wildlife Service, both the Atmospheric Environment Service and the Environmental Protection Division are involved in a commendable amount of contracting out and technology transfer.

The *Parks Service*, the western arm of which is headquartered in Edmonton, does little scientific research except in the field of restoration of cultural materials and historic sites, none of which is currently managed out of B.C. The Atmospheric Environment Service has its major research facility (of about 200 people) in Downsview, Ontario, but does have a low level research activity in Vancouver which is reported on below.

Only the *Conservation and Protection Branch* does research of any substance in B.C., almost all of which is performed by the *Canadian Wildlife Service* and is related to migratory birds. The migratory bird research is centred at the Reifel Bird Sanctuary.

In addition to their work with migratory birds, the core research of this group is directed towards understanding coastal and estuary systems (particularly those under the constant threat of change), and environmental toxicology.

The group is particularly proud of its contributions to the ecology of old growth forests as it bears on forest birds, of its early studies of the effects of dioxins on herons, of its decade long studies of sea bird colonies, and of its studies of waterfowl and their habitat which have been of great value in understanding some of the effects of civilization's advance into the wetlands, particularly the Fraser River estuary.

Environmental Protection, also a part of the Conservation and Protection Branch, plays a role which is primarily investigative and regulatory. It does not itself perform any research, but is a major user of other people's research results and other department's research programs. The Division's Director

estimates that between 10% and 20% of the effort of the division is directed towards science based recording activities and the brokering of commercial development projects amongst the various agencies which fund R&D. A notable example of this latter activity is the development if the BIO-P sewage treatment process which was first put into use in Kelowna.

The *Atmospheric Environment Service* (AES) does not do formal research in Vancouver. Those activities take place at AES's research facility in Downsview, Ontario. However, the Vancouver office is active in some applied research and development activities and have enjoyed considerable success, albeit on a modest scale.

Since most of B.C.'s weather approaches from the Pacific Ocean, where weather observation posts are sparse, the group has become expert at interpretation of satellite information. This enforced interest has led to their playing a prime role in the development of some very successful data analysis tools, most notably the Metdas system, contracted to MacDonald Dettweiler and Associates, using the now defunct Unsolicited Proposal Fund. It has also led to some better techniques for forecasting marine weather, especially the dangerous rapidly developing storms, on which considerable progress has been made. The group is seeking funding to finance development of an expert system to encapsulate some of the specialist knowledge needed for correct interpretation of data in order to make good forecasts.

The Green Plan is an important new development. Announced about a year ago, and planned for execution over six years (an extension from the originally announced five year time frame) at a cost of over $3 billion, it includes substantial funding for research, including a $250 million Science and Technology Action Plan administered by Environment Canada out of the office of the Science Advisor in Ottawa. Very little of this money has been expended to date, since the program is only just getting up and running.

3.5 The Department of Fisheries and Oceans

The Department of Fisheries and Oceans operates two major research facilities in B.C., the Pacific Biological Station (PBS) at Nanaimo (with subsidiary facilities in West Vancouver and Cultus Lake) and the Institute of Ocean Sciences (IOS) north of Victoria. These are managed by the Regional Director of Science, who reports to the Regional Director General.

The approximate budgets of the Fisheries and Oceans facilities in 1991/92 were as follows:

Facility	Est. Annual Budget($000) Internal Funds	Person Years Scientists	Person Years Total
Biological Science			
Pac. Biol. Stn.	$20,820	47	185.1
West Van. Lab.	incl. above	incl.	40
Cultus Lake Lab.	incl. above	incl.	10
TOTAL (Biol.)	**$20,820**	**47**	**235.1**
Institute of Ocean Sciences (IOS)			
Oceanography	$9,588	25	80.5
Hydrography	$5,665	11	89.2
TOTAL (IOS)	**$15,253**	**36**	**169.7**
TOTAL	**$36,073**	**83**	**404.8**

The *Pacific Biological Station* was founded in 1908. When combined with its West Vancouver Laboratories, it is the largest Federal research presence in B.C., with an annual budget of $20.8 million, 47 research scientists and 235 employees all told. The Institute of Ocean Sciences has a budget of $15.3 million, employs 36 research scientists and has a total complement of 170 persons, however only about 40% of the effort is devoted to research, with the remainder devoted primarily to the production of charts and to scientific data collection. Together the two organizations account for about 36% of Federal intramural R&D expenditures in B.C.

The Pacific Biological Station has devoted a large fraction of its resources over the years to the single minded pursuit of understanding the salmon and its environment, where it wanders and how it finds its way, who besides humans eats it and what it eats. In that time, it has of course tackled other questions as well, but an understanding of the Pacific salmon has been its main endeavour, and it has enjoyed considerable success in this undertaking. The station is proud of the fact that approximately 10 percent of the annual salmon catch results from the salmonid enhancement activities resulting from their research. In more recent years, it has made important advances related to salmon farming (primarily at its West Vancouver Laboratory), and has been influential in a number of other areas including assessing the effects of pollution and of driftnet fishing, and research into the life cycle of other fish varieties, including shell fish and herring.

The *Physical and Chemical Sciences (Oceanography) Division of the Institute of Ocean Sciences* is responsible for a variety of oceanographic research projects, including studies of the influence of the oceans on climate and the greenhouse effect (where it has been at the leading edge). Institute scientists study such events as *El Nino* which brings warm water onto our

coast, and affects our fish stocks. More generally, they study ocean circulation, and other physical and chemical properties of the ocean. The laboratory is deeply involved in environmental assessment issues such as toxic plankton studies, ocean dumping, site-specific pollution problems and oil spills. IOS personnel were heavily involved in the responses to the *Nestucca*, the *Exxon Valdez* and Persian Gulf oil spills, particularly in the area of predicting spilled oil movement.

The *Hydrography Division* of IOS employs some 89 people, approximately 15 of whom are involved in research. The Division produces 42% of the charts made in Canada, covering the West Coast, the Western Arctic and important inland waterways. In addition, the Division produces tide and current tables and cruising guides, and plays a major role in Canada's Tsunami warning system, with tide gauges located along the coast to indicate an approaching sea wave. The Division has been active in technology development and transfer, and has some impressive accomplishments to its credit in this sphere.

IOS activities have been pivotal to the development of the ocean industry in B.C., an industry which employed about 350 people in 1990, and had gross sales of about $25 million. The doubling time of sales in the industry is presently about 5 years.

3.6 Forestry Canada

Forestry Canada started life about 90 years ago as the Dominion Forest Service, a branch of the Department of the Interior. Since that time the Forestry Service has had its home in a number of departments, including Mines and Resources (1936-1950), Northern Affairs and National Resources (1953-1969), Dept. of Forestry (1960-1966), Fisheries and Forestry (1969-1971), Environment (1971-1978 and 1980-1984), Agriculture (1984-1988) and finally Forestry again in 1988!

The Pacific Forestry Centre (PFC) was established at its present site in 1965, having moved from quarters in downtown Victoria where the Dominion Forest Pathological Laboratory had been established in 1940. The first priority of the Pathology Lab in 1940 was to investigate decay in the Sitka spruce being logged in the Queen Charlotte Islands for the manufacture of aircraft for use in the war. Historically, the focus of the centre has been on reducing the depredations of our forests from "bugs and fire", but this role has broadened in recent years. In very general terms, wood losses from disease and fire come to 10% and 5% respectively of the cut in B.C. in an average year.

About 48% of the budget and about 19% of the manpower at the centre is involved with industry, trade and development, while the remaining 52% of the budget and 81% of the manpower are devoted to research, including technical and administrative support of research, and the delivery of science.

The budget of the Pacific Forestry Centre for 1991/92 was as follows:

Facility	Est. Annual Budget($000) Internal Funds	Person Years Scientists	Person Years Total
Research	$14,120.0	47	148
IT&D[2]	$13,236.8	0	34
TOTAL	**$27,356.8**	**47**	**182**

The region maintains a District Office at Prince George with a staff of five persons including a research manager (at the same site as the Agriculture Canada Prince George Research Station). The Prince George group is involved in research and technology transfer projects developed through discussion with local clients.

Some of the key research projects undertaken by the Pacific Forestry Centre include:

- the successful development of methods to control the export of the Pinewood Nematode in lumber scheduled for export to Europe.

- research in the remote sensing of soil compaction to help quantify environmental impacts. Licensing/patenting of this development is in process.

- forest ecosystem dynamics research, aimed at understanding how ecological processes and biodiversity may be affected by changes in the forest and atmospheric environments.

- survey of forest insect and disease conditions in B.C. and the Yukon.

- functional pest management systems development for Douglas-fir beetle, Douglas-fir tussock moth, Douglas-fir seed orchard pests, nursery diseases and dwarf mistletoes.

- population model development for the mountain pine beetle. The model is being used for forest management purposes, and similar models for

[2]Industry, Trade and Development, an economic analysis and business issues activity.

understanding the impacts of a variety of other pests including laminated root rot, spruce weevil and budworms are being developed.

- the Canadian Forest Fire Danger Rating System which is now used operationally in many countries of the world was developed (in co-operation with other Forest Canada facilities).

- alternative silviculture and wood harvesting systems are being researched and tested.

Forestry Canada also provides international seed testing and certification, nursery pest diagnosis, genetic finger printing for gypsy moth, watershed hydrology modelling and biocontrol of weeds as services to industry.

A major new initiative is research into the forest resource management implications of remote sensing, combined with a program to develop the appropriate technology for forestry applications.

It is interesting to note that Forestry Canada spends about 20% of its R&D budget in B.C. This is a relatively small percentage compared to the 35% B.C. share of total Canadian value added from the forest products industry, and its 53% share of Canadian logging revenues.

3.7 The Department of National Defence

The Defence Research Establishment, Pacific (DREP) at Esquimalt has been in operation since 1948, and currently employs 130 persons, 49 of whom are defence scientists. About 50% of the work is classified in nature, with the emphasis of the research being in mine counter-measures, underwater electromagnetic surveillance (magnetic anomaly detection (MAD)), underwater acoustic surveillance in the Arctic and the Pacific, and some aspects of materials technology. The annual budget in 1991/92 was about $14.2 million including salaries but excluding the cost of operating the research vessel.

An important part of DREP's mission is to contribute to the growth of the defence-related science and technology base in Canadian universities and in industry. In 1991/92 outside contracts amounted to $3.6 million, about 73% of which went to B.C. industry and 27% to B.C. universities. Some of these contracts have had an important impact, notably those to Professor Barrodale at the University of Victoria which led directly to the establishment of Barrodale Computing, and to ISER Ltd. of Port Coquitlam for the development of two autonomous underwater vehicles (ARCSS and DOLPHIN), whose potential markets are estimated to be substantial, though as yet largely unrealized.

Two contracts in the fields of underwater surveillance have led to sales in the $50-$100 million range. In these instances, neither of the companies involved, Computing Devices of Canada and CAE Electronics, are based in B.C.

The establishment has the use of the *CFAV Endeavour*, a 75-metre Department of National Defence research vessel commissioned in 1975. The ship is crewed by civilians but the operating costs are covered by the Queen's Harbour Master. The *Endeavour* is also used by the Institute of Oceanographic Studies, universities, and other Chief Research and Development (CRAD) laboratories.

3.8 The National Research Council

The National Research Council has a commanding presence in astronomy in B.C., which is the home of the Dominion Astrophysical Observatory just outside Victoria, and the Dominion Radio Astrophysical Observatory just outside Penticton. Both groups are a part of the Herzberg Institute of Astrophysics (HIA) which is headquartered in Ottawa. In addition, NRC carries out engineering research from two locations adjacent to the U.B.C. campus in Vancouver.

Negotiations are currently underway between NRC management and the B.C. government concerning the transfer of the rest of the Herzberg Institute of Astrophysics from Ottawa to a new building on the University of Victoria campus. The Council is also considering a plan which could see the two Vancouver-based engineering groups merged with others to form a substantial new engineering institute which it would plan to house in the old Forintek building adjoining the U.B.C. campus.

The move of the Ottawa sections of the Herzberg Institute to Victoria would involve the transfer of approximately 80 scientists and technicians.

Should a new engineering institute be formed in Vancouver it could eventually involve approximately 95 additional NRC scientists and supporting staff, and up to 40 research associates, collaborators and guest workers. It is anticipated that NRC expenditures at the new institute would be about $7.5 million p.a., which would be a significant increment to Federal research expenditures in B.C.

The budgets of the four NRC laboratories for 1991/92 were as follows:

Facility	Est. Annual Budget($000) Internal Funds	Ext. Revenue	Person Years Scientists	Person Years Total
Science				
DAO	$3,750	$300	11	41
DRAO	$2,636	?	7	28
Engineering				
Tribology	$1,325	$200	6	18
Info. Tech.	$900	$75	4	10
TOTAL	**$8,611**	**$575**	**28**	**97**

The *Dominion Astrophysical Observatory* (DAO) was inaugurated in 1918 and has since made major contributions to our understanding of the universe. The original 1.8 m reflecting telescope, continually upgraded over the years with first class instrumentation, is still a useful device with heavy demands for observing time from astronomers around the world, particularly for the observation of rapidly changing phenomena which require a large number of viewing days. A second reflecting telescope (1.2 m) was added at the site in 1962. It too is heavily booked.

The early fame of the observatory rested on the study of binary stars, and the first accurate mapping of the Milky Way galaxy. Work is continuing in these fields, as well as in studies of super massive black holes, bright star clusters, and dark matter - the elusive missing mass which is known to be there because of its observed gravitational effect, but which is otherwise undetected and certainly not yet understood.

Laboratory scientists also participate in experiments and instrumentation development related to the Canada France Hawaii Telescope (CFHT), a 300 ton 3.6 m reflecting telescope at the summit of Mauna Kea, an extinct 4,200 m volcano on the island of Hawaii, which is believed to be the best terrestrial viewing site in the world. It is also very actively involved in planning for Canada's participation in the two 8 m Gemini telescopes, one to be located in Chile to view the southern hemisphere and one at Mauna Kea. If this project proceeds as expected, DAO will house the Canadian project office for the venture.

The *Dominion Radio Astrophysical Observatory* (DRAO) is located in a valley surrounded by low mountains, about 20 km south-west of Penticton. The site was selected in 1958 because of the protection it provides against man-made emission, and is one of the best sites in North America for radio astronomy at centimetre wavelengths.

DRAO operates two major radio telescopes as national facilities, a (recently upgraded) seven element aperture-synthesis telescope and a 26 metre single reflector telescope. The observatory also operates solar radio telescopes whose data is made available as a service to the scientific and technical community.

Much of the effort of all staff is devoted to running the facility for outside experimenters from Canadian universities and elsewhere.

The instruments at the DRAO site have found their greatest use in the study of interstellar matter in our own (Milky Way) galaxy because of their ability to make images of large regions of very faint, extended radio emissions. The solar radio program has recently been transferred from Ottawa to Penticton, continuing a world acclaimed 40 year series of important basic solar flux measurements and of research into the mechanisms at work in the sun. The solar data is also used for investigations of the Earth's upper atmosphere, and for studies of climatic change.

The two engineering groups currently operating in Vancouver are the *Tribology Mechanics section of the Institute of Mechanical Engineering*, and the *Systems Laboratory*, formerly a part of the Institute of Information Technology, and now associated with Mechanical Engineering.

The *Tribology Mechanics* group has been in existence in Vancouver since 1972. Its focus is on applied studies in tribology (friction) and mechanics aimed at solving major generic and some specific problems faced by Canadian industry. Perhaps its greatest research success has been its work on rail wear, which is estimated to save the Canadian railways approximately $100 million p.a. Other projects include studies of braking problems on the Canadarm (in space), noise reduction associated with the Vancouver Skytrain, the development of a log yarding system, and a variety of other theoretical and practical friction studies.

The *Systems Laboratory* of the Division of Mechanical Engineering was created in 1987 with the objective of focusing on information technology of relevance to the resource and transportation industries. Since that time it has broadened its clientele and perspectives and focuses on the development of practical applications of "Symbiotic Systems" software and object-oriented programming.

CHAPTER 4 - AGRICULTURE CANADA

4.1 General Overview

The Agriculture Canada Research Branch operates 41 establishments in Canada, three research centres, 27 research stations (four of which are in B.C.), and 11 experimental farms. The total branch budget for 1990-91, including $20 million of external funding, was $280 million. Income from licensing arrangements and royalties were $100,000 and $154,000 respectively. In 1988/89 Department of Agriculture intramural expenditures in B.C. were $21.9 million, or about 6.9% of the total. Total staff in 1990-91 was 3,428 of whom 866 were classified as scientific and professional.

The five key operating principles of the Research Branch as enunciated in the Agriculture Canada Strategic Directions Working Paper #9 (August, 1991) on page 6 are:

1. Assist the Canadian agri-food industry to access, develop and use technology.
2. Focus research on projects with economic or environmental significance for the sector, but which have less potential for early returns on investment.
3. Provide strong leadership and co-ordination at the national level by building partnerships with other R&D players.
4. Consolidate research programs which have a common focus at fewer locations.
5. Enhance both internal and external communications to accelerate the adoption of new technologies.

In B.C., the consolidation process enunciated in the fourth principle has resulted in the closing of the Sidney Experimental Farm in 1987/88, and the near closure of the Prince George Experimental Farm in 1991. In 1992 the Kamloops Research Station (and Prince George) come under the direction of the Summerland Research Station.

The approximate budgets of the four major stations in B.C. and their subsidiary facilities for 1991/92 were as follows:

Facility	Est. Annual Budget($000) Internal Funds	Person Years Scientists	Person Years Total
Agassiz Res. Stn.	$3,288	16	58
Kamloops Res. Stn.	$2,233	6	30
- Prince George Exp. Farm	incl. above	0	2
Summerland Res. Stn.	$6,079	24	86
Vancouver Res. Stn.[1]	$4,279	20	56
TOTAL	**$15,879**	**66**	232

The *Agassiz Research Station* was established in 1886 under the terms of the Experimental Farm Act, and was one of the five original experimental farms in Canada. The station operates two farms in Agassiz covering 665 hectares, and a substation at Abbotsford with 8 hectares.

The research program at the station encompasses both animal and crop sciences. The Animal Science Section focuses on dairy and poultry research, with the former directed towards dairy cattle nutrition, including energy and protein utilization and forage management. The poultry program, operated with the tangible support of the B.C. poultry industry, emphasizes nutrition, physiology and animal behavior. (Some of the research is literally aimed at improving productivity through keeping the hens happier.)

Crop research at Agassiz encompasses management, pre- and post-harvest physiology, entomology and plant pathology of greenhouse and field vegetable crops, plus management of small fruits, including kiwi fruit and hazelnuts. Work on hydroponic growth of greenhouse vegetables seems to hold particular promise. The Agassiz Research Station enjoys close ties with the Faculty of Agriculture at U.B.C.

The *Kamloops Research Station* was established at its present site in 1947, although Agriculture Canada has conducted research in the Kamloops area since 1928. Researchers at the station investigate problems related to the beef cow-calf industry in the interior of B.C. The station also administers the Experimental Farm at Prince George. Researchers at Kamloops develop and transfer technology in the fields of range and pasture management, soil fertility, plant ecology, poisonous plants, bloat, plant winter hardiness, forage agronomy, quality of conserved forages and ruminant nutrition.

Administration of the Prince George Experimental Farm was transferred to Kamloops from the Research Station at Beaverlodge, Alberta in 1979. There

[1]Data for Vancouver is for 1990/91. Data for 1991/92 was not available.

are now no scientists permanently stationed at Prince George. In 1965 consideration was given to closing the Kamloops Station as an austerity measure, however, during a meeting of the B.C. Cattlemen's Association in that year, the then Minister of Agriculture was persuaded to change his mind. On April 1, 1992 the Kamloops Research Station was consolidated with the Summerland Research Station. It remains to be seen whether an active research program will survive in Kamloops.

The *Summerland Research Station* was established in 1914, and is now headquartered in an impressive new office and laboratory complex complete with pilot plant facilities for food research, which was opened in 1987. The building's facilities include a 640 m^2 computer controlled greenhouse with 18 distinct compartments and about 75 controlled environment growth chambers. The station is on a land base of 320 hectares, of which about 90 hectares are irrigated and available for tree fruit and viticulture research. Research on tree fruit production and protection is also conducted at substations in Kelowna and Creston. Effective April 1, 1992 the Kamloops Research Station (and the Prince George Experimental Farm) also became substations of Summerland.

The research program at Summerland is designed to serve primarily the tree fruit and grape industries in the interior of B.C., but many programs have relevance to fruit production and utilization across Canada. Research disciplines represented at Summerland include entomology, plant pathology, food processing, pomology, viticulture, soil science and agricultural engineering. A major program is underway in "integrated pest management", which combines chemical, cultural and biological control methods. The station is proud of its accomplishments in food processing, including the development of "vitaminized" apple juice, a variety of fruit juice blends, and some world class wines.

The *Vancouver Research Station* is the main centre for plant virus research in Canada. In addition, it serves the coastal areas of B.C. on problems of insects and plant diseases in horticultural crops, and the interior of the province on pest problems of vegetables, forages, and potato crops.

Although formally established in 1960, a laboratory of plant pathology was founded in 1946, and other research groups also congregated in Vancouver prior to occupancy of the then-new building on the U.B.C. campus in 1960.

The station is organized into three main research sections, virus chemistry and physiology, plant pathology, and entomology.

Some major accomplishments of the laboratory in recent years include:

- Production of a stable DNA copy of the Cucumber Necrosis virus. This work is aimed at obtaining a better understanding of the role of various proteins and RNA sequences in plant disease induction, with implications for controlling the spread of plant virus diseases.
- Preliminary characterization of a baculovirus regulatory gene, which will aid in the development of biological control agents.
- Successful introduction of the coat protein gene of the potato leafroll virus into Desiree and Burbank potatoes. Transgenic plants with engineered resistance to specific viruses should provide an alternative to chemical controls.
- Studies of tuber flea beetles in potatoes, western flower thrips in greenhouse vegetables and aphids on strawberries.
- Various studies connected with raspberries and strawberries, including the introduction of new cultivars (esp. the Tulameen raspberry and the Shuswap strawberry).
- Development of monoclonal antibodies and serological techniques for the rapid diagnosis, detection and characterization of plant pathogenic bacteria and viruses.

A 1988 Agriculture Canada publication entitled *Agriculture and Food in British Columbia* provided the following background information:

- In 1986, farm cash receipts in B.C. were about $1 billion, which was about 4.9% of the Canadian total. In the same year, there were 19,063 farms in B.C., about 6.5% of the Canadian total.
- Farms with annual revenues below $25,000 are categorized as "part time farms". Part time farms comprise 73% of all B.C. farms, and account for 26% of revenues.
- For part time farmers in B.C., farm revenues accounted for about 1% of average family income. For commercial farmers, 38% of family income on average is derived from farming. (The equivalent average Canadian figure is 49%.)

In 1990 British Columbia ranked sixth among the provinces in farm cash receipts which were estimated at $1.143 billion, up 2.6% from the previous year.

In Table 4.1 a listing of Farm Cash Receipts for 1990 is given, with the order of listing being descending revenue for B.C. farmers. Both B.C. and Canadian total revenues are shown for each product category. Note that while

revenues from floriculture and nursery products rank third in B.C., (and B.C. has almost 19% of the Canadian market), there appears to be no research in this area undertaken by Agriculture Canada in the province. On the other hand, this is a field in which U.B.C. is very active, so an Agriculture Canada activity may not be needed. It is also noteworthy that Apples, Berries and Grapes are currently quite small revenue earners in the total picture for B.C. While there is an apparent discrepancy between Agriculture Canada research expenditures and B.C. farm revenues in these two cases, this should not be taken to imply that the balance of research of Agriculture Canada is necessarily wrong. Some crops are small, but growing rapidly (such as blueberries), and can profit from relatively intense research just at this time. Others (such as the apple and grape industries) are going through some turbulent times, and may need extra support until a resolution is found.

Farm Cash Receipts	B.C. $millions	Canada $millions	B.C. Share of Cdn. Prod'n
Dairy products	$250	$3,136	8.0%
Cattle and calves	$208	$3,983	5.2%
Floriculture and nursery	$125	$672	18.6%
Hens and chickens	$122	$972	12.6%
Vegetables	$92	$681	13.5%
Eggs	$65	$473	13.7%
Hogs	$56	$2,033	2.8%
Berries and grapes	$50	$151	33.1%
Apples	$37	$127	29.1%
Potatoes	$17	$412	4.1%
Other tree fruits	$12	$56	21.4%
Forage, grass seed, hay etc.	$10	$71	14.1%
Other crops and livestock	$99	$6,889	1.4%
Total crops and livestock	**$1,143**	**$19,656**	**5.8%**

Source:FCR 21-001

Table 4.1 - Farm Cash Receipts for Various Agricultural Products - 1991

4.2 Agassiz Research Station

OVERVIEW

The *Agassiz Research Station* was established in 1886 under the terms of the Experimental Farm Act, and was one of the five original experimental farms in Canada. The station operates two farms in Agassiz covering 665 hectares, and a substation at Abbotsford with 8 hectares.

In 1991/92 the station was funded at a level of $3.3 million by Agriculture Canada, and attracted additional outside funds of $328,000. Fifty-seven persons were employed at the station, sixteen of whom were scientists.

The research program at the station encompasses both animal and crop sciences. The Animal Science Section focuses on dairy and poultry research, with the former directed towards dairy cattle nutrition, including energy and protein utilization and forage management. The poultry program, operated with the tangible support of the B.C. poultry industry, emphasizes nutrition, physiology and animal behavior. (Some of the research is literally aimed at improving productivity through keeping the hens happier.)

Animal Science Section resources include a feedmill; land, barns, etc. to support 150 dairy cattle; barns and facilities for 1,300 layers and 40,000 broilers and turkeys; and facilities for behaviour trials.

Crop research at Agassiz encompasses management, pre- and post-harvest physiology, entomology and plant pathology of greenhouse and field vegetable crops, plus management of small fruits, including kiwi fruit and hazelnuts.

Work on hydroponic growth of greenhouse vegetables seems to hold particular promise. The Agassiz Research Station enjoys close ties with the Faculty of Agriculture at U.B.C.

The Soil and Environment Protection Section has had success in modelling selenium metabolism and in measuring its concentration. It has also been working on the adoption of new corn and grass hybrids.

1. Contact

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2. Mandate/Objectives

The Agassiz Research Station develops production systems for poultry and dairy cattle, studies vegetable and small fruit production, and develops greenhouse and storage systems for vegetables. It also conducts soil and fertilizer management research in support of sustainable agriculture, particularly in the Fraser Valley.

3. Budget (in $000)

Year	Operating	Contract	Capital	Total
1991/92	3,023.4	328.0	265.0	3,288.4

1. Revenue is from the sale of milk ($280K) and cows/calves ($12K). This was returned to consolidated general revenues and was not available to fund research.
2. In addition, external revenues in the amount of $404.5K in 1990/91 were realized for a variety of projects.

4. Person Years

Year	Research Scientists	Scientific Support	Admin.	Total
1991/92	15.75	34.75	7	57.5

1. Livestock Section personnel include 3 scientists and 15 support staff.
2. Crops Science Section personnel include 8 scientists and 15 support staff.
3. Soil & Environmental Protection Section personnel include 4 scientists and 5.5 support staff.
4. Administration personnel total seven.

5.a Principal Criteria for Success

Livestock Section: For applied research projects the principal criteria are the solution of an industry-identified problem and the adoption of that solution by the industry. For more basic research the criterion is the identification and resolution of problems before they impact on the industry.

Crops Science Section: It is usually implicit in the goals of a project that useful technology and significant scientific information will result. The relative importance of these two elements will change from project to project, or over the course of a long-term project. Success indicators for useful technology are: patents, licenses, invited articles

in trade publications, acceptance by the industry, and introduction of the technology into standard practice or its legislation as essential practice. Success indicators for significant scientific information include precedence, citation and peer review. A project that produces the founding article in a new branch of scientific investigation could be viewed as ultimately successful by this definition.

Soils & Environment Protection Section: Acceptance of scientific concepts by scientific community and of practical technology by the industry.

5.b Most Successful Projects

Livestock Section

1. The detailed knowledge of nutritional and managerial factors influencing milk composition which allows rational decisions to be made relative to a multiple-component pricing system for milk.
2. Guidelines for the effective use of silage and hay additives.
3. Isolation of immunoglobulins from abattoir blood for supplementation of newborn calves.
4. On-farm progesterone test kits.

Crops Science Section

1. The development of silicon for control of powdery mildew on greenhouse cucumbers. This project produced a new product and technology and also spawned a new field of investigation, the role of silicon in disease resistance and other physiological mechanisms in plants.
2. Several years ago Agriculture Canada scientists introduced sawdust as a growing medium for greenhouse tomatoes and cucumbers which revolutionized the industry in B.C. Currently over 90% of all greenhouse vegetables are produced hydroponically using either sawdust or some other inert medium.
3. Studies on cold-hardiness and extension of growing season for crop plants have produced much in the way of new technology and products, e.g. the now extensive use of floating mulch and other forms of row covers and mulches.
4. A project on the biological control of pests of greenhouse vegetable crops has made significant contributions to new technology, e.g. the identification and testing of three predators of western flower thrips, and the development of optimum colour for sticky monitoring traps for this pest.

Soils & Environment Protection Section:

1. New technologies for measuring selenium are widely accepted.
2. Computer model for selenium metabolism is gaining in prominence.
3. Adoption of new corn and grass hybrids and new ways of managing them.

6.a Patents, Technical Papers and Citations

This information is available in the Research Branch Reports referred to in 10.a (p. 52).

6.b Spin-off Companies

Crops Science Section

The formation of Applied BioNomics, a private company producing insect parasites for controlling greenhouse vegetable pests, was the direct result of technology developed at Saanichton Research Station[2] on Vancouver Island. Mr. Eliot of Applied Bionomics worked as a technician at the Station and was encouraged to produce insect parasites on a commercial basis. The company was established with provincial and federal assistance. As well as supplying B.C., it ships insects to Alberta, Ontario, and California, and now employs over 12 people.

6.c New Products Resulting from Research

Livestock Section

1. A U.S. company has taken up the immunoglobulin work. Interest in the results of the project has been expressed by Lakeside Feeders of Brooks, Alta.
2. Milk progesterone cowside kits - Helix Biotech Corp. of Richmond, B.C. Ten PY and a potential revenue of $2 million.
3. A number of feed companies have developed marketing programs for various additives based on the results of our projects. For example, hay and silage additives resulting in $1 million sales and four PYs.

Crops Science Section

Over the past five years of research, new products include:

1. Amblyseius cucumeris - a predatory mite for control of western flower thrips in greenhouses. Sales estimated in millions of dollars. Applied BioNomics and insectaries throughout the world.
2. Hypoaspis spp - predatory mite for the control of fungus gnats in western flower thrips in greenhouses. Current sales estimated in tens of thousands of dollars; primarily in use in Canada. Applied BioNomics is the only major producer at present.
3. Orius tristicolor - predatory bug for control of western flower thrips in greenhouses. Now being introduced. Sales potentially enormous as it has utility outside greenhouse vegetables. Applied BioNomics the only major producer at present.
4. Yellow and blue traps - identification of blue as an attractive colour for western flower thrips has led to the production of sticky blue monitoring traps by several firms worldwide, including PheroTech of B.C.
5. Silicon for control of powdery mildew - National Silicates of Toronto. Estimated sales of $100K to $500K depending on acceptance by industry.
6. Greenhouse peppers - Almost $8 million in B.C. in 1990.
7. The establishment of the B.C. kiwifruit industry is the direct result of research done by Agriculture Canada, first at Saanichton Research Station and latterly at

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[2] Dr. Molnar was the Director of the Saanichton Research Station prior to its closing in 1985 when he moved to Agassiz.

Agassiz. Current value of this crop is $1 million with a future potential of up to $10 million. Currently there are 29 growers in B.C.

Soils & Environmental Protection Section

1. Yield improvement (2%) in new corn hybrid developed outside B.C. and tested in co-operation with the B.C. Ministry of Agriculture, Fisheries and Food. Value to B.C. producers: $100K - $200K p.a.

2. Improved disease resistance and winter hardiness in new grass varieties developed outside B.C. and tested in co-operation with the province. Approximate value: $100K p.a.

6.d Intangible Benefits

Livestock Section

1. Awareness of potassium and nitrate excess in forage and the need to control fertilizer practices more closely.

2. More accurate detection of heats leading to more efficient reproduction for dairy cattle.

3. Animal welfare issues such as cow handling and behaviour.

4. Seminars, media interviews, etc. to promote public awareness of research on animal welfare.

5. Improvements in chicken and turkey productivity and carcass quality through the development of improved lighting programs.

Crops Science Section

1. Several programs are concerned with crop quality which has led directly to increased sales and reduced losses for many commodities, e.g. greenhouse cucumbers and field-grown parsnips. The improvements also led to improved consumer perception and a willingness to purchase B.C. products. Ultimately this research contributes to the stability of the horticultural sector in B.C.

2. Research in biological control and Integrated Pest Management (IPM) has reduced pesticide use and impacted several other areas. For example, the use of living mulches in raspberry and vegetable crop weed management which reduces herbicide use, and soil erosion and compaction.

3. The greenhouse vegetable industry is currently adopting recirculating hydroponics technology, due in part to research at Agassiz. Not only does this reduce fertilizer use, but it also eliminates the leaching of fertilizer into the groundwater.

Soils & Environmental Protection Section

1. Improved cropping technology for higher yield, greater self-sufficiency and reduced environmental impact.

2. Forage produced on over 100,000 hectares in south coastal B.C.

3. Information on cropping practices and manure management has been incorporated into provincial recommendations and guidelines. Examples include the use of winter cover crops, BCMAFF manure application guidelines,

new forage species and harvesting practices, fertilizer requirement, and advice to feed companies on mineral requirements.

6.e Outstanding Research Scientists Attracted to B.C.

Tom Scott and various graduate student and post-doctoral fellows associated with our livestock programs, e.g. Inma Inez.

Nick Pyke, Dept. of Scientific and Industrial Research (DSIR) New Zealand; Mr. W. Yang and Mr. J. Ma, People's Republic of China.

6.f Benefits to Provincial R&D Establishments

Livestock Section

1. Close cooperation with the Department of Animal Science at UBC including ten graduate and several undergraduate students, and collaborative projects with four faculty members.
2. Practicum training for students from the agriculture program at the University College of Fraser Valley (UCFV).
3. Instruction and training for international delegations hosted by the provincial government, e.g. recent training sessions for Chinese, Japanese, Polish and Ukrainian delegates. This year the Station hosts a visiting scientist from China, and is providing training for a PhD candidate from Spain, six students from France, two from Holland, and one from Germany.
4. Seminars at UBC and UCFV to promote understanding of animal welfare issues.
5. Adjunct professorship in Dept. of Animal Science, UBC; guest lecturer.
6. Chairman of Advisory Committee to Agricultural Program at UCFV.

Crops Science Section

The Station provides the following benefits to universities and colleges:

- Access to expertise
- Consultation
- Student employment (currently four)
- Graduate student training (currently eight)
- Facilities and land
- Access to co-operative funding systems, e.g. the (now defunct) unsolicited proposals system.

Soils and Environmental Protection Section

The station provides a large pool of expertise in agricultural research in coastal B.C. on soils, forage, and vegetable production. This is utilized by universities in the following ways:

- Adjunct professors (Zebarth, Buckley, Toivonen)
- Lectures at UBC and UCFV
- Training graduate students and post-doctoral fellows (five).
- Summer student employment (two) in co-op programs.

7. Important Collaborative Organizations

Livestock Section

Within B.C. - UBC, the B.C. Veterinary Laboratory and the B.C. Poultry Extension (particularly S. Paulson) and the poultry commodity sectors and allied industries.

Elsewhere - other Agriculture Canada research stations, particularly Ottawa and Kentville; U. of Alberta (F.E. Robinson); U. of Saskatchewan (H.L. Classen); U. of Manitoba (W. Guenter and L. Campbell); and I. Duncan and F. Hurnik at Guelph.
In the area of dairy cattle nutrition and management, collaborative studies have been carried out with the U. of Manitoba as well as local dairy farms. Exchange of information also occurs between our dairy program and the BC. Artificial Insemination Centre at Milner, B.C. (e.g. calving difficulty and milking speed) and B.C. Dairy Herd Improvement Services (e.g. milk composition and central data collection).

Crops Science Section

In basic research - SFU, UBC and other universities; other Research Stations; and in some cases the province.

In technology transfer - the province, R&D and technical service supply companies such as PheroTech, Applied BioNomics and fertilizer companies.

Client industries are also important, e.g. Greenhouse Vegetable Growers Research Council, Lower Mainland Horticultural Improvement Association, vegetable co-operatives, and individual growers.

Soils & Environmental Protection Section

- UBC - Departments of Soil Science, Plant Science, Animal Science and BioResource Engineering
- USDA North Dakota (Grand Forks) and Washington State (Pyallup)
- BCMAFF - Variety development, management practices
- Environment Canada (Inland Waters) and other Agriculture Canada Research Stations.

Role Models - Resource facility for kinetics analysis, U. of Washington, (Buckley); Grass Research Institute (Hurley) and U. of Wales, U.K.; and DSIR in New Zealand.

8. Suggestions on Ways B.C. Might Derive Greater Value from the Work at This Establishment

Livestock Section

1. Animal Research Committee/Agriculture Research Committee encourages industry input to develop research priorities, but does not provide the infrastructure to support proposals. A system to review applications and provide written acknowledgement that a proposal addresses a priority established by the committee would enhance its effectiveness.
2. Support information transfer between producers and poultry researchers. This could be done by affiliating an extension specialist for each sector of the industry with appropriate research establishments.

3. Closer association with BCMAFF livestock specialists and collaboration with the District Agriculturist in the utilization of DATE funding and in the use of provincial funds directed toward research in livestock.

Crops Science Section

1. Provide a granting system to drive priority basic research which Station researchers can access directly.
2. Help small commodity groups build research funds to be used to support applied research conducted by the province, the universities, and private consultants as well as the Station.
3. Establish a mechanism for universities to place graduate students at government labs for part or all of the research portion of their degree. Currently this happens only if the university cannot duplicate a government lab: ideally it should happen whenever there is a linkage in research programs. The mechanism should cover graduate student stipend, some living/travel costs and a portion of the operating costs and should be geared to provide links between basic and applied research.
4. Commodity-based and problem-oriented joint workshop programs targeted to operation staff rather than administrators. Communication is probably most important.
5. Co-located related activities wherever possible.
6. Take a proactive approach to priority setting within BCMAFF; involve Station scientists at the ground level; make sure that lines of communication are open at all times.

Soils & Environmental Protection Section

1. Increased access to provincial funding, for example the B.C. Science Council.
2. More opportunities for student placement.
3. Enhanced co-operation with the universities.

9. Industry Overview

Livestock Sector

Poultry Industry: The B.C. Poultry Sector Profiles included in the PACST library provide in-depth summaries of growth and projected change in market opportunities. In 1992/93 the chicken meat industry is projecting a plateau in demand while turkey sales continue to climb.

Table egg sales are decreasing per capita, but B.C.'s increasing population has allowed farm gate sales to remain constant. Price, food quality, food safety and animal welfare issues dominate market demand of poultry meat and eggs. It would be useful to encourage the food technology industry to respond to egg producers' demands for new lines of (value-added) products.

Research into poultry production (behaviour management, physiology and nutrition) must address food safety/quality and animal welfare issues as well as ensure sustainability of environmentally friendly practices.

Sector	No. of Producers	Farm Cash Receipts ($ k)	Production ($ mill)
Egg Laying	155	381.5	60.6
Broiler Hatching	42		12.5
Turkeys	56	415.0	23.0
Chickens	254	418.0	95.0

Dairy Industry: This industry contributes the largest portion of farmgate receipts within the agriculture sector. There are 1,345 producers, 88,000 cows with a total capital resource of $920 million and annual inputs of $217 million. Farmgate receipts total $225 million, while retail sales of fluid milk in B.C. total $475 million.

Crops Science Sector

Field vegetable industry: Planted acres are generally shrinking due to urbanization and foreign competition. Urbanization is causing problems due to the increased visibility of farm activities. Maintenance of markets is dependent on quality of produce. In 1990 gross sales were approximately $56 million, about 20% of which was processed sales. In 1984, total sales were about $57 million - about the same as in 1988 with a similar processed sales ratio. More significantly, total production has decreased from 329 million pounds in 1988 to 297 million pounds in 1990. A trend to decreasing production has been evident since 1986. Over that period, about 400 acres have gone out of production.

Greenhouse vegetable industry: Planted acres have been steadily increasing by about 10% per year with about 118 acres under glass in 1990. Total sales have almost doubled since 1985 and are currently at $29 million. Although the local market continues to be important to the industry, export markets have expanded tremendously. Quality is of prime importance and biological control is most frequently used for pest control. Aggressive marketing, continued quality improvement and improvements in pest and disease control are primary challenges.

Small fruit industry: Faces much the same challenges as the field vegetable industry. Raspberry sales in 1990 were about $9 million, filberts almost $500K, and kiwifruit almost $1 million.

10.a Recent Publications

The following documents were provided and are included in the PACST library:

1. *Research Branch Reports*, Agriculture Canada, for the years 1986, 1987, 1988, 1989/90 and 1991 (excerpt).
2. *Agassiz Research Station Research Highlights 1989-1990*, Agriculture Canada, 1991.
3. *Agassiz Research Station 1886-1986*, Agriculture Canada, 1986.
4. *Pacific Field Corn Association Field Corn Report 1991*, Agriculture Canada, 1991.
5. *Field Corn Variety Recommendations 1992*, Pacific Field Corn Association, 1992

6. *Management Techniques to Improve the Carcass Quality of Heavy Tom Turkeys*, Agri-Food Regional Development Subsidiary Agreement, Sept. 1991

10.b Key Scientific or Technical Papers

Copies of the following papers were provided and are on file.

1. "Resistance of alfalfa cultivars to brown root rot", *Can. J. Plant Sci. 71*, pp 211-213, Jan. 1991
2. "Effect of companion crops on forage establishment in south coastal British Columbia", *Can. J. Plant Sci. 70*, pp 777-784, July 1990.
3. "Performance of alfalfa strains grown in mixture with smooth bromegrass as affected by management", *Can. J. Plant Sci. 71*, pp 1029-1037, Oct. 1991.
4. "Spectral responsiveness of Frankliniella occidentalis (Thysanoptera: Thripidae) determined by trap catches in greenhouses", *Environmental Entomology Vol. 19 No.5*, pp 1229-1241, Oct. 1990.
5. "Biological control of fungus gnats, Bradysia spp. (Diptera: Sciaridae) and western flower thrips Frankliniella occidentalis (Pergande) (Thysanoptera: Thripidae) in greenhouses using a soil-dwelling predatory mite, Geolaelaps sp. nr. Aculeifer (Canestrini) (Acari: Laelapidae)", *The Cdn Entomologist Vol. 122*, pp 975-983, Oct. 1990.

11. Major Projects

1. Management techniques to improve the carcass quality of heavy tom turkeys.

Budget: $187,630 funded by Agriculture Canada, BCMAF and the B.C. Turkey Association under the ARDSA productivity enhancement program.

Duration: Two years ending Sept. 1991

The project involved approximately 4,000 turkeys in four experiments and was successful in identifying factors effective in reducing breast button development in heavy tom turkeys and in improving carcass grades. Factors tested included lighting, temperature, and litter coarseness and type. Breast button incidence was reduced by 50% through avoidance of coarse litter material and the use of sawdust rather than newspaper bedding.

Significance: This project provided growers with information aimed at improving product quality, and demonstrated the negative impact on turkey growth and well-being from the current practice of toe clipping. A new lighting program was developed which shows promise of improving liveweight, reducing mortality, and improving carcass quality in comparison with conventional lighting.

2. The effect of feeding barley or wheat-based diets supplemented with beta-glucanase enzymes on pullet growth, egg laying and nutrient utilization.

Budget: $185K from Agriculture Canada and $27K in supplied enzyme from FinnFeeds Int. The return on egg sales is estimated at $30K, for a net cost to AgCan of $155K.

Duration: April 1992 - July 1993

The project is investigating the effects of high and low fibre diets and enzyme supplementation on pullet growth, egg production and quality, gut development, and nutrient utilization. The research is focusing on issues such as the post-peak egg drop, and the improvement of nutrient utilization which could significantly reduce feed costs while reducing the excess excretion of nitrogen and phosphorus into the environment.

Links: Dr. H.L. Classen at U. of Saskatchewan and Dr. F.E. Robinson at U. of Alberta.

3. Minimizing environmental impact of field corn production with double-cropping systems.

Budget: $92.5K under Canada-B.C. Soil Conservation Agreement and approximately $100K in land, scientific facilities, equipment, etc.

Duration: 1991-94

Significant steps have been taken to reduce nutrient loss over the winter from 10,000 hectares of fodder corn fields in south coastal B.C. Our goal is to provide farmers with a management strategy to reduce this loss into the groundwater by leaching and surface-water runoff while maintaining cropping practice profitability.

Research Links: Closely tied to provincial strategies; work carried out by UBC post-graduate student.

4. Optimum trace element intake and utilization by ruminants.

Budget: 1-1.5 PY per year.

Duration: 1987-1992

New technology is being developed for determining nutritional requirements in animals and human beings. Innovative techniques are required to provide quantitative recommendations when complex interactions occur among dietary components. Limitations inherent in conventional nutritional trials have been overcome by incorporating stable isotope tracer methodology and by analyzing the results with the aid of computer modeling. Results of recent studies with the essential trace elements selenium and copper show that these techniques have considerable potential in nutritional science.

Research Links: Canadian researchers involved in the development of this technology include Dr. W.T. Buckley of Agassiz, Ms. K.M. Koenig of Lethbridge Research Station, and Drs. J.A. Shelford (Animal Science) and G.K. Eigendorf (Chemistry) of UBC. A joint project between Agriculture Canada and the U.S. Department of Agriculture has also been initiated.

5. Determination of trace elements and their stable isotopes in biological materials by inductively coupled plasma mass spectrometry.

Budget: 1-1.5 PY per year.

Duration: 1987-1991.

New analytical techniques were developed which provide greater versatility and depth to trace element research.

6. Influence of the time of manure application on loss of soil nitrogen by leaching and de-nitrification.

Budget: $174,885 joint project with UBC funded by Canada-B.C. Soil Conservation Agreement.

Duration: 1991-94.

The objectives are to obtain information about the time and magnitude of nitrogen processes with the application of liquid dairy manure on silage corn, and to use this field information to calibrate a computer simulation model.

This is one of the few projects which has been conducted on manure management. The results will be important in the development of environmentally friendly guidelines for the land application of manure.

7. Influence of the rate of poultry manure application on raspberries on the potential for nitrate leaching.

Budget: Funded under the Canada-B.C. Soil Conservation Agreement ($45,270) and a collaborative agreement with the Fraser Valley Egg Marketing Board.

Duration: 2.5 years, 1991-94.

Our purpose is to obtain a better understanding of nitrogen processes in the soils overlying the Abbotsford Aquifer. This is an important aquifer in the Fraser Basin which is very sensitive to groundwater contamination. The results of this work will be used to develop management recommendations to reduce the risk of contamination in the aquifer and to aid in the development of guidelines for the land application of poultry manure.

8. Embryonic mortality in dairy cows - a nutritional etiology

The objectives of this study are to determine the relationships between ration protein degradability and blood urea nitrogen, milk urea nitrogen, and reproductive efficiency. This collaborative study includes veterinarian Dr. J. Shelford of UBC, 12 dairy farmers, and a PDF student from Poland. The three-year study has already identified problems associated with excess nitrogen intake and cow health. The participation of the 12 dairy farms has assured direct and immediate application of the results.

9. New technologies for estrus detection - temperature radiotelemetry and electronic activity monitoring.

This cooperative study with Dr. A. Kennedy of the Dept. of Animal Science, U. of Manitoba and the Manitoba Milk Marketing Board, utilizes temperature telemetry to identify ovulation times in cows and hence allows more accurate scheduling of breeding times. The use of pedometers to measure cow activity has also proven to be effective in identifying estrus in dairy cows.

10. Electronic monitoring of the individual intake of supplements by grazing animals

This has been accomplished through a cooperative project with Dr. M. Tait, Dept. of Animal Science UBC, and JCU Electronic Designs. The study has identified the extensive variation in the intake of supplemental molasses blocks and mineral supplements by animals on pasture. The information generated by this project has been useful to the companies formulating molasses blocks (e.g. Ralston Purina), and in the formation of mineral supplements for grazing animals.

4.3 Kamloops Research Station

Overview

The Kamloops Research Station was established at its present site in 1947, although Agriculture Canada has conducted research in the Kamloops area since 1928. Researchers at the station investigate problems related to the beef cow-calf industry in the interior of B.C. The station also administers the Experimental Farm at Prince George. Researchers at Kamloops develop and transfer technology in the fields of range and pasture management, soil fertility, plant ecology, poisonous plants, bloat, plant winter hardiness, forage agronomy, quality of conserved forages and ruminant nutrition.

Administration of the Prince George Experimental Farm was transferred to Kamloops from the Research Station at Beaverlodge, Alberta in 1979. There are now no scientists permanently stationed at Prince George. In 1965 consideration was given to closing the Kamloops Station as an austerity measure, however, during a meeting of the B.C. Cattlemen's Association in that year, the then Minister of Agriculture was persuaded to change his mind. On April 1, 1992 the Kamloops Research Station was consolidated with the Summerland Research Station. It remains to be seen whether an active research program will survive in Kamloops.

1. **Contact**

Dr. Klaas Broersma, Director (from September, 1991)

Address

Kamloops Research Station
3015 Ord Road, Kamloops, B.C., V2B 8A9

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Prince George Research Station
R.R #8, Site #125, Comp. #9, Prince George, B.C. V2N 4M6

Tel: (604) 376-5565 Fax: (604) 565-7646

2. **Mandate/Objectives**

The two primary research objectives of the operation are:

1. *Beef Research Program:* By 1994, as part of a continuing program, to provide new information and technology transfer that will assist beef producers in the

B.C. interior to retain access to forested rangeland for grazing, to reduce the hazards to production from anti-quality components in range and cultivated plant species, and to improve the utilization of conserved forages, thereby increasing the efficiency of beef production by 5% relative to production levels achievable with a 1986 level of input.

2. *Forages Research Program:* By 1994, as part of a continuing program, to provide new information and technology transfers that will permit a 10% increase in cost effectiveness of forage production and utilization through yield and quality improvement of native range, legumes and cereals, seeded grasses, and conserved forages while maintaining the soil resources.

3. Budget (in $000)

Year	Operating Kam	Operating PG	Operating Total	Capital Kam	Capital PG	Capital Total
1986/87	$200	$104	$304	$414	67	$481
1987/88	235	84	318	286	120	406
1988/89	229	89	318	445	39	484
1989/90	254	80	334	365	49	414
1990/91	238	88	326	161	63	224

1. Externally funded contracts are undertaken for the Science Council of B.C., the B.C. Cattlemen's Association, ARDSA and others. In 1990/91 these amounted to $797.8K for both locations, and in 1991/92 to $791.1K.
2. A list of land, buildings, and facilities at Kamloops and Prince George is included in the PACST library.
3. The above costs do not include salary costs. Salary costs for 1991/92 have been estimated at an average of $52.6K p.a. for a total of $1,683K.

4. Person Years

1. KAMLOOPS

Year	Research Scientists	Scientific Support	Admin.	Other	Total
1986/87	5	6	4	10	25
1987/88	5	6	4	13	28
1988/89	6	7	4	13	30
1989/90	7	7	4	12	30
1990/91	6	8	5	10	29
1991/92	6	9	5	10	30

2. PRINCE GEORGE

Year	Research Scientists	Scientific Support	Admin. & Other	Total
1986/87	3	3	6	12
1987/88	2	3	6	11
1988/89	2	3	6	11
1989/90	1	2	7	10
1990/91	1	2	6	9
1991/92	0	2	0	2

5.a Criteria for Success

Acceptance and utilization of research results and findings.

5.b Most Successful Projects

1. The use of Rangeland Seed Drill to revegitate depleted rangeland.
2. Development of poorly drained organic and glysolic soils to produce domestic forages. Development of meadows include water control, re-seeding to tame grass and fertilization.
3. Fertilization of rangelands and clearcuts.
4. Understanding cattle and deer (wildlife) interactions on the range.
5. How to manage and control timber milkvetch poisoning.
6. Poisonous plants and their biochemistry.
7. A better understanding of cattle and tree seedling interactions.
8. Learning about bloat and bloat control.
9. Intercropping or double cropping with barley and ryegrass.
10. Use of protein supplementation of cattle to improve performance.
11. Increased benefits from soil testing by using a multi-nutrient extractant.

6.a Patents, Technical Papers and Citations

We do keep records of patents and technical papers published. Patents have only recently become important as a source of royalties for the developing facilities. The development of patents in the past was not encouraged because of high costs and because Agriculture Canada was considered as a public institution. Technical papers are very important to our scientists as a measure of productivity and influence. They also provide a permanent record of scientific findings. Citations are generally used to document importance of certain research publications and for measuring the influence of our work.

6.b Spin-off Companies

No spin-off companies have been formed as a result of R&D at this establishment, but we have worked with R&D from companies in seed coating and animal feed additives.

6.c New Products Resulting from Research

No new products have been produced or sold as a result of R&D performed here. The Kamloops Research Station has been involved in testing and evaluating new cultivars of forage crops for registration and eventual sale to the agriculture producers. Impact and revenues are unknown, but are significant.

6.d Intangible Benefits

Intangible benefits of R&D performed by this establishment are, of course, difficult to measure and determine. Research for the cattle industry has been conducted by the Federal Government in B.C. since 1928 and the expertise of research establishments such as Kamloops has been utilized by agriculture, universities and government extensively.

Information has been disseminated to the agricultural community resulting in product improvements (Rangeland Seed Drill, Meadow Plow, feed quality, etc.), environment improvements (fertilizer efficiency), conservation (improvements of over-grazed rangelands, seeding clearcuts, etc.), and public awareness (field days, open house, student tours for universities, colleges and local schools, providing research fact not fiction, etc.).

6.e Outstanding Research Scientists Attracted to B.C.

Three scientists who come to mind and have international reputations in their respective fields are Drs. E.W. Tisdale (1935-39), A. McLean (1948-86), and W. Majek (1972-). One must also remember that a dedicated research team is necessary for a research scientist to be outstanding.

6.f Benefits to Provincial R&D Establishments

Collaborative work with universities and colleges has allowed us to share expertise, funding, and specialized equipment for mutual benefit. Teaching institutions often do not have available the "outdoor laboratories" required to give their students field experience. The use of students is beneficial to both the students and the employer as it provides labour and training.

7. Important Collaborative Organizations

- Other Agriculture Canada research centres, especially in Western Canada
- Universities: UBC, U. of Alberta, U. of Saskatchewan, etc.
- B.C. Ministry of Agriculture, Fisheries and Food
- B.C. Ministry of Forests
- B.C. Cattlemen's Association
- B.C. Feeders Association
- B.C. Forage Council

- Other producer groups

8. Suggestions on How B.C. Might Derive Greater Value from the Work at This Establishment

1. More co-operation in research.
2. Multi-disciplinary research teams which include research from a number of different organizations such as Agriculture Canada, universities, provincial government, producers, etc.
3. Better understanding of research requirements.
4. Knowing the research priorities of other disciplines.

9. Industry Overview

Our main efforts are directed towards the beef cattle and forage production industries through research in soil fertility, forage production and quality, and beef cattle production on the range and in the feedlot.

Farm cash receipts from the sale of cattle and calves in 1987 were $186 million or 17.4% of the total of $1,072 billion The cattle population of B.C. was 641,000 in 1990. In 1987 the industry contributed over half a billion dollars to the B.C. economy and accounted for 12,000 jobs. In addition, it contributes significantly to other industries such as meat packers, trucking, farm equipment, feed and seed, hay sales, etc. Meat processing in B.C. is a $750-million per year industry.[3]

10.a Recent Publications

1. *Research Highlights, Kamloops Research Station and Prince George Experimental Farm*, Agriculture Canada, 1990-91
2. *Research Highlights, Kamloops Research Station and Prince George Experimental Farm*, Agriculture Canada, 1989.
3. *Kamloops Range Research Station 1928-1985*, Agriculture Canada, 1986.
4. *History of the Range Research Station, Kamloops British Columbia, 1928-1984*, Agriculture Canada, 1986

10.b Key Scientific or Technical Papers

Listings of published technical papers are to be found in the *Research Station Kamloops, British Columbia* reports from 1986-88 and from the *Research Branch Report* excerpts for 1989/90 and 1991 in the PACST library.
Copies of approximately 30 recent publications from the Station are also filed in the PACST library.

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[3] Source: B.C. Cattlemen's Association.

11. Major projects

The PACST library includes a study database for the following projects:

KAMLOOPS RESEARCH STATION

1. Habitat use and nutritional quality of rangeland diets of cattle and deer in southern interior B.C.

There is considerable controversy over whether range use by cattle is detrimental to mule deer populations but little information is available on the diet and nutritional status of B.C. rangeland animals. Documentation would both alleviate conflict and provide a basis for management schemes to optimize both cattle and deer production.

Three years of direct observation of cattle and deer grazing on seeded clearcuts, unlogged forested range showed only 11% similarity and little competition with cattle for food. All ranges produced dietary deficiencies of protein, phosphorous, sodium, iodine, zinc and copper, while native forested range and grasslands produced deficiencies in selenium. Grasslands were also deficient in magnesium.

Intensive grazing by cattle reduced the growth of timber milkvetch by 50% and its toxicity by 75%. Forcing cattle to graze the early growth would therefore reduce the toxification potential, but the plant is not a preferred food and the degree of grass use that would force cattle onto milkvetch would probably be detrimental to range health and condition.

Duration: 1979-1994

2. Management of B.C. seeded clearcuts, forested rangelands, and grasslands to optimize beef production and to sustain the range forage resource in a highly productive condition.

Significance: Beef production in B.C. relies on grazing bottom land hayfields and grasslands in spring and fall, and forested rangelands and clearcut logged areas in summer. Information is lacking on the sustainability of the range resource with such variables as carrying capacity at different seasons, the effects of different grazing systems, frequency of use, etc. A sound database on which to base management decisions is required.

Research Links: B.C. Ministry of Forests and Lands, UBC Plant Science Department.

Duration: 1979-1993

3. Identification, metabolism and quantitative determination of anti-quality components of cultivated and native forages such as low larkspur (Delphinium nuttallianum) and stinkweed (Thlapsi arvense).

Achievements: Concentrations of the neurotoxic alkaloid MLA (methyllycaconitine) in low larkspur were found to vary not with stage of growth, but with elevation, higher concentrations being found at higher elevations. The toxic metabolite from stinkweed was identified as allylthiocyanate, and the ruminal conditions under which it is released from the glucosinolate were determined.

Research Links: U. of Calgary

Duration: 1979-1990

4. New alfalfa cultivars and feed additives for the prevention of pasture bloat.

Economic gains would be substantial if alfalfa bloat could be reduced or eliminated because the forage could be utilized to its optimum without risk of livestock loss. Newly developed "bloat-safe" varieties of alfalfa and a number of preventative remedies were tested and found unsatisfactory. Grazing and feeding trials indicated a higher susceptibility to bloat in the morning. A bulletin on Bloat in Cattle was published (see PACST library).

Duration: 1979-1991

5. Supplements to enhance forage digestibility and utilization by beef cattle.

Fibre digestibility was significantly increased when cellulose in the form of filter paper was added to corn and barley silage and alfalfa hay. Microbial protein production was also increased in alfalfa hay.

Duration: 1987-1990

6. Compositional factors of forages and their effects on silage and hay quality.

Nitrogen and compositional analysis of prepared silage samples showed that the maximum conservation of herbage nutrients would be possible if direct cut silage were ensiled with appropriate additives to increase dry matter content, avoid seepage, and to facilitate rapid pH depression.

Duration: 1987-1989

7. Evaluation of forage harvesting, handling and storage systems for feedlot cattle.

Chemical analysis of alfalfa and corn silages suggest that good quality silage can be prepared in bunkers or agbags without the use of silage additives.

Duration: 1988-1993

8. Effect of grazing low- or high-alkaloid containing reed canarygrass on yearling steer performance.

Trials showed that steers grazing timothy hay gained weight faster than those on reed canarygrasses. Preliminary data indicate that the low alkaloid variety of reed canarygrass tended to produce higher gains than the high alkaloid variety. Digestibility values of grasses were determined from chemical analysis.

Duration: 1988-1990

9. Effect of oil seed meal or whole seed supplementation to grass silage on nutritional performance of cattle.

The high energy yielding feed grain required for backgrounding, growing, or finishing cattle is not adequately produced in B.C. and must be hauled in at high freight prices. Some 80% of the interior's weaned calves are now shipped out of province for finishing because of the prohibitive cost. However, if energy- and protein-dense oil seed feeds could be obtained at lower cost and utilized effectively by cattle the viability of finishing cattle on forages in B.C. could be realized.

Duration: 1989-1994

10. Climate, soil and ecological relationship of rangelands in the southern interior of B.C.

Maps and diagrams of wetland and agricultural production in B.C. were produced. Yield response and nutrient concentration were studied in reed canarygrass, crested wheatgrass and irrigated alfalfa. The response of grass and forest land to nitrogen, phosphate and potash fertilization is being evaluated and will form the basis for assessing the affects of weather factors on forage and fertilization.

Research Links: B.C. Ministry of Environment

Duration: 1979-1993

11. Management of cultivar selection, seeding and harvesting for winter survival and stand persistence of alfalfa.

A method for early evaluation of winter damage to alfalfa was developed and a field study conducted to compare methods of estimating stored alfalfa reserves in autumn and winter. Low temperature cold acclimation was studied in alfalfa and birdsfoot trefoil. High winter survival rates were found in cultivars with low fall growth rate, but these were also found likely to produce reduced spring-summer yield

The Hayden method for calculating symplasmic resistance and cell membrane capacitance was applied to ten different plant organs and, in contrast to previous assumptions, both resistance and capacitance were found to decrease with increasing frequency.

Duration: 1986-1994

12. Forage variety testing to test the adaptability and yield of legume and grass cultivars in interior B.C. for licensing and producer recommendations.

Duration: 1987-1994

Research Link: B.C. Ministry of Agriculture

PRINCE GEORGE EXPERIMENTAL FARM

1. To determine the status of macro and micro nutrients, phosphorous fixation capacities and liming response of the major agriculture soils in the central interior of B.C.

Duration: 1987-1991

2. Evaluate grasses, legumes, cereals and their mixtures for adaptation to the central interior of B.C. for quality, and make fertiliser recommendations; evaluate several multi-element soil extractants.

Research Links: UBC Department of Plant Science; Soil Testing Laboratories

Duration: 1980-2000 (est.)

4.4 Summerland Research Station

Overview

The *Summerland Research Station* was established in 1914, and is now headquartered in an impressive new office and laboratory complex complete with pilot plant facilities for food research, which was opened in 1987. The building's facilities include a 640 m^2 computer controlled greenhouse with 18 distinct compartments and about 75 controlled environment growth chambers. The station is on a land base of 320 hectares, of which about 90 hectares are irrigated and available for tree fruit and viticulture research. Research on tree fruit production and protection is also conducted at substations in Kelowna and Creston. Effective April 1, 1992 the Kamloops Research Station (and the Prince George Experimental Farm) also became substations of Summerland.

The research program at Summerland is designed to serve primarily the tree fruit and grape industries in the interior of B.C., but many programs have relevance to fruit production and utilization across Canada. Research disciplines represented at Summerland include entomology, plant pathology, food processing, pomology, viticulture, soil science and agricultural engineering. A major program is underway in "integrated pest management", which combines chemical, cultural and biological control methods. The station is proud of its accomplishments in food processing, including the development of "vitaminized" apple juice, a variety of fruit juice blends, and some world class wines.

In 1991/92 the station had a total budget of $6.1 million, and employed 92 persons, of whom 24 were research scientists.

1. **Contact**

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Address

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2. **Mandate/Objectives**

The Summerland Research Station conducts multidisciplinary research on tree fruits and grapes including:

- the development of sustainable production systems including soil and water resource management, control of plant growth and productivity, and improving fruit quality;
- the integrated management of pests and diseases; and
- cultivar and rootstock breeding and evaluation.

It also studies food technology for horticultural crops including chemistry, sensory evaluation, storage and packaging, fermentation and other practices.

3. **Budget ($000)**

	Operating				
Year	Pay	Non-Pay	Revenue	Capital	Total
1988/89	3631.1	1168.5	?	649.8	5449.4
1989/90	4068.0	1345.8	400	1041.3	6600.1
1990/91	4215.8	1217.1	400	642.9	6202.8
1991/92	4156.0	1155.8	415	694.0	6078.8
1992/93	Estimated to be approximately equal to 1991/92.				

Operating and Capital funds are allocated by the Branch to the "A" base budget. Small amounts of contract funds are requested to fund specific projects, and come from Federal government sources outside the Department of Agriculture. Most of the contract funding comes from outside the government, most notably, about $250 K p.a. in salaries paid by the Okanagan Federated Shippers Association who employ one scientist and four technicians working in fruit storage research at the Summerland facility. Included in the 1992/93 total is about $50 K of contracts from the U.S.

4. **Person Years**

Year	Research Scientists	Scientific Support	Admin.	Total
1988/89	26	54	12	92
1989/90	26	54	12	92
1990/91	25	55	11	91
1991/92	24	52	10	86
1992/93	24	52	10	86

Scientific support includes technical scientific, technical general, field support and building and equipment support.

5.a Criteria for Success

New technologies developed.
Adoption of these technologies.
Important contributions to science (scientific merit).

5.b Most Successful Projects

Apple and cherry cultivar development.
Codling moth control by sterile insect release (SIR).
Growth regulator use in apple and cherry production.
Mating disruption for insect control.
Development of new fruit products and processes.
Irrigation/fertigation technology.
Waste water management.
Minor element nutrition of tree fruits.
Canopy management to improve wine grape quality.
New and improved fruit storage technology.

6.a Patents, Technical Papers and Citations

Records are kept, but these are difficult to access on short notice.

6.b Spin-off Companies

Agriforest Nurseries (tissue culture lab) , Kelowna.
B.C. Fruit Growers Test Orchard Ltd.
Integrated Crop Management Inc., Okanagan Centre.
Okanagan-Kootenay Sterile Insect Release Board
Swanson and Turbomist concentrate sprayers, Penticton
B.C. Fruit Growers Certified Budwood Association Ltd.

6.c New Products Resulting from Research

Modified Atmosphere Packaging plant of Five B Produce in the Fraser Valley, who use Summerland's packaging techniques to distribute "fresh" herbs and other edibles.
The B.C. fruit industry uses fruit storage techniques developed at Summerland to extend fruit storage time by up to six months.
Juice technology, Sun Rype (200+ employees).
New apple and cherry varieties (including license agreements with Chile, Japan, Australia, New Zealand, France and the Netherlands).
Fruit drying, Okanagan Dried Fruits (40 employees).
New wines and wine products.
Sun Dew (18 employees).
ABCO Blancher (Rapid heat transfer technologies, a Summerland and Nova Scotia collaboration).

6.d Intangible Benefits

Waste water utilization.
Orchard management practices.

Reduced pesticide use.

6.e Outstanding Research Scientists Attracted to B.C.

Recent exchange of researchers with the Institut National de Recherche Agricole (INRA) in France.
H.A. Quamme on cold hardiness
Hiroshi Sugisawa, University of Tokyo, entrapping volatiles.

6.f Benefits to Provincial R&D Establishments

Student employment (10-14 during the summer)
Training for Masters in Pest Management, Simon Fraser (about 10 students for several weeks once a year).
Collaborative projects involving graduate students and post-doctoral fellows.

7. Important Collaborative Organizations

UBC and Simon Fraser
B.C. Research
Other Agriculture Canada Research Stations

8. Suggestions on Ways B.C. Might Derive Greater Value from the Work at This Establishment

Greater encouragement for adoption of new technology by tree fruit and food processing industries.

9. Industry Overview

The farm-gate revenue for tree fruits in B.C. is approximately $50 million. The corresponding number for grapes is $3-$4 million.

The food processing industry in B.C. has gross revenues of $3.8 billion annually, but this figure includes the processing of animals and fish. Only about 13% (or $500 million) relates to the horticultural sector.

Detailed industry profiles for the apple, apricot, cherry (sweet and sour), peach, pear and plum industries were provided and are stored in the PACST library.

10.a Recent Publications

The following documents are on file in the PACST Library:

1. *Research Programs at the Summerland Research Station*, a 9-page overview of current research at the station.
2. *Agricultural Research in Canada's Pacific Region*, 1986. An overview of research programs at Agriculture Canada's Pacific Region stations.
3. *Profile of the Grape and Wine Industry of British Columbia*, 1991. A 65-page booklet prepared for the B.C. Ministry of Agriculture, Fisheries and Food.

4. *Industry Profiles for Tree Fruit Sectors*, 1991. Draft reports on the apple, apricot, cherry (sweet and sour), peach, pear and plum industries prepared for the Okanagan Valley Tree Fruit Authority. Each report is between 10 and 35 pages.

5. *The Summerland Research Station Commemorative Symposium*, 1987. A 5-page speech prepared for the official opening of the facility.

6. *Accomplishments: Pomology and Viticulture Section 1985 to 1990*, an 8-page report prepared for the 1989 Research Branch Review.

7. *Commodity Sector Profiles 1991-1992*, a 42-page draft review of the tree fruit sector prepared for the Okanagan Valley Tree Fruit Authority.

8. "Horticulture and horticulturists in British Columbia, Canada"; *HortScience, Vol. 19(3)* pp 334-475, June 1984.

9. Brochures and guides to the Summerland Research Station

10.b Key Scientific or Technical Papers

A list of published papers is provided in the annual Research Branch Report published by Agriculture Canada. The 1991 copy is stored in the PACST library, and lists 27 refereed publications and 17 "technology transfer" publications.

11. Major Projects

The research scientists are grouped into four sections as follows:

1. Entomology and Plant Pathology

This section includes eight scientists.

It is responsible for developing safe, economical controls for insects, mites, and diseases of tree fruits and grapes. Emphasis is placed on integrated pest management, a system of combining host resistance with chemical, cultural and biological control methods. The long-term objective is to produce fruits and grapes with reduced pesticides. A continuing research program is essential to ensure that the British Columbia fruit industry, which depends upon high production efficiency and superior quality, maintains its competitive position. It is estimated that codling moth damage alone costs B.C. farmers approximately $10 million per year.

Major pests and diseases under investigation include codling and bud moth, leafrollers, pear psylla, pear mites, cherry fruit fly, leafminers, crown and root rot, crown gall, replant problems, brown rot and alternaria on soft fruits, botrytis on grapes, post-harvest apple and pear rots, apple scab, powdery mildew, and virus diseases of tree fruits and grapes. A research program on pesticide resistance in relation to control efficiency and environmental quality is also pursued. The pest management program is closely linked with SFU, the eastern provinces and the U.S.

Recent accomplishments include the implementation of the sterile insect release program (SIR) to eradicate codling moth from the Okanagan, Similkameen, and Kootenay Valleys in conjunction with pheromone-based mating disruption and granulosis virus; the identification of a sex pheromone for the eye-spotted bud moth; the development of biological control for crown and root rot and replant problems; the

development of a rapid detection technique for little cherry disease; and the chlorination of dump water to protect pears from rotting in storage.

2. Food Processing

This section includes four research scientists and four technical support personnel.

The section provides a basic and applied research program directed to the value-added processing of horticultural crops. The program leads to the development of improved, more efficient processes and products. As well, both indigenous and acquired technology is transferred to the food industry through provision of food processing expertise or the knowledge where such expertise exists. The research program, combined with linkages to UBC's Food Science Department, B.C. Research's Food Technology Centre, and research collaborations and connections throughout Canada and the world, provides the basis for this important work.

Recent accomplishments include the transfer of station-generated modified atmosphere packaging technology to a Surrey company, resulting in the installation of a packaging line allowing the worldwide marketing of fresh B.C. produce. The company has indicated that five jobs and $275K first year sales may be attributed to this development.

The ABCO blancher, an Agriculture Canada developed machine capable of extremely efficient utilization of thermal energy, was transferred to a lower mainland vegetable processor. Recognition of the advantage inherent in this machine resulted in the sale of two blanchers in B.C. It is manufactured by ABCO Industries of Canada and represents Canadian-developed superior technology, manufactured and sold in Canada.

The station's research has resulted in production modifications for B.C. apple juice manufacturers to reduce haze development and improve product quality. Historically, methods and equipment for the production of more than a hundred fruit and vegetable products have been developed at Summerland.

Vintning techniques capable of producing world-class wines from Okanagan-grown grapes have been developed and promoted by members of this section. Such wines are regularly manufactured by the B.C. wine industry. Presently, computer-assisted recognition of analytical profiles of wines produced by different vintning techniques, and the connection of these profiles to flavour and quality is expected to result in further product improvements through selection of optimum processing techniques. Generally these computer-recognition techniques have further application in the optimization of blends or formulations, the replacement of taste panels, and fraud detection.

The development of essential-oil extraction technologies may lay the basis for a culinary flavour industry for B.C. Enhanced fruit drying technologies are supporting the development of a valuable industry in the Okanagan Valley which shows promise for increased export of Okanagan fruit.

3. Pomology and Viticulture

This section includes eight research scientists.

This section is responsible for areas of fruit and grape production research ranging from creation of new cultivars to storage of their fruit. The main research programs include breeding of apples and sweet cherries; evaluating rootstocks and developing pruning and training systems for pome and stone fruits and grapes; conducting physiological studies on winter-hardiness, on tree growth, flowering processes and fruit maturation; and developing improved fruit storage systems.

Recent accomplishments include the development of new technology for the rapid and efficient multiplication of fruit trees on clonal rootstocks; development and introduction of new technology for fruit tree nurseries involving the use of plastic mulches; development, naming and popularization of Lapins sweet cherry; development, naming and introduction of Sovereign Opal and Simone grapes; and characterization of the relationship between canopy microclimate and the development of important flavour components of wine grapes.

4. Soil Science and Agricultural Engineering

This section includes five research scientists.

Current research projects include the development of new methods and associated technology to determine packaging film permeability in support of industry research on development of modified atmosphere packaging; the development and testing of soil sterilization techniques to overcome replant problems of fruit tree and ginseng growers; and the design, modification and monitoring of fruit drier equipment in direct support of industry value-added initiatives regarding dried fruit products (e.g. Wilson's Touch of Sun and Testalinda Holdings).

A range of projects involved with environmental sustainability are currently underway, including soil fertility and plant nutrition, soil management and conservation, efficiency of water use and irrigation, and environmental organic chemistry.

Specific projects include:

1. Development of methods to overcome nutrient deficiencies such as Cu and Ca;
2. Development of methods to overcome replant problems (co-operation with ARDSA, BCFGA, and BCMAF) in support of industry initiatives to maximize economic advantages of high-density plantings;
3. Adaptation of novel fertigation (fertilization through irrigation) methods to improve fertilizer use efficiency and reduce groundwater pollution (supported by funding from Okanagan Valley Tree Fruit Authority (OVTFA)) and with research links and funding from Washington and Oregon;
4. Assessment and development of an apple fruitlet mineral analysis program in support of industry efforts to segregate and sell fruit based on susceptibility to storage disorders. The program is also funded by NRC-IRAP and Okanagan Federated Shippers Association;
5. Development of regulated irrigation management schemes for crops grown in the area in order to optimize quality and yield. A regulated deficit irrigation study on super-high-density plantings is currently underway at the grower test orchard funded by OVTFA;

6. Determination of aerial concentrations of codling moth pheromone in orchards during mating disruption in support of efforts to reduce industry reliance on pesticide use for insect control;

7. Determination of herbicide mobility in soils to assess risk and avoid ground and surface water contamination;

8. Assessment of effectiveness of cherry fumigation in support of industry efforts to access the Japanese market.

In the future the research group will be increasingly looking to work with outside groups interested in developing and marketing environmental technologies.

4.5 The Vancouver Research Station

Overview

The research station is the main centre for plant virus research in Canada. In addition, it serves the coastal areas of B.C. on problems of insects and plant diseases in horticultural crops, and the interior of the province on pest problems of vegetables, forages, and potato crops.

Although formally established in 1960, a laboratory of plant pathology was founded in 1946, and other research groups also congregated in Vancouver prior to occupancy of the then-new building on the U.B.C. campus in 1960.

The station currently employs about 56 persons, 20 of whom are research scientists. Its annual budget of $3 million exclusive of salaries (or about $5.1 million including personnel costs) includes $706K for contracts.

The station is organized into three main research sections, virus chemistry and physiology, plant pathology, and entomology.

Some major accomplishments of the laboratory in recent years include:

- Production of a stable DNA copy of the Cucumber Necrosis virus. This work is aimed at obtaining a better understanding of the role of various proteins and RNA sequences in plant disease induction, with implications for controlling the spread of plant virus diseases,
- Preliminary characterization of a baculovirus regulatory gene, which will aid in the development of biological control agents,
- Successful introduction of the coat protein gene of the potato leafroll virus into Desiree and Burbank potatoes. Transgenic plants with engineered resistance to specific viruses should provide an alternative to chemical controls.
- Studies of tuber flea beetles in potatoes, western flower thrips in greenhouse vegetables and aphids on strawberries.
- Various studies connected with raspberries and strawberries, including the introduction of new cultivars (esp. the Tulameen raspberry and the Shuswap strawberry),
- Development of monoclonal antibodies and serological techniques for the rapid diagnosis, detection and characterization of plant pathogenic bacteria and viruses.

1. **Contact**

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2. **Mandate/Objectives**

Conducts research on viruses of significance to agriculture and develops ways to control insect pests and plant diseases of crops in the coastal region. It also breeds new cultivars of raspberries and strawberries.

3. **Budget (in $000)**

Year	Operating (incl. Salaries)	Ext. Revenue	Capital	Total
1990/91	$3,042.4	$706.0	$530.4	$4,278.8

1. In 1990-91 the principal sources of these revenues (some of which were in kind) were:

Lower Mainland agricultural associations:	$173,600
NSERC:	$79,400
US-based agricultural associations (Calif., Wash., Ore.):	$30,500
Other Fed. and Prov. government sources (e.g. IDRC, EEF, N.B. Agric., Alta. etc.):	$222,350
Other sources:	$146,400

2. Agriculture Canada have evolved a system whereby External Revenues may be retained for research purposes provided the management of the revenues is contracted out to a third party.

3. Budgetary information for 1991/92 was not available.

4. **Person Years**

Year	Research Scientists	Scientific Support	Admin.	Total
1990/91	20	30	6.5	56.5

1. Includes an 8.5 ha farm site at Abbotsford with one employee on site.
2. The closure of the Sidney Research Station led to an increase of 4.4 py in 1987-88 and subsequent years (from 51.6 py).
3. Person year data for other years was not available.

5.a Criteria for Success

Impact on the Canadian agricultural community, with particular emphasis on the coastal regions of British Columbia.

5.b Most Successful Projects

Some of the laboratories' major achievements relate to monoclonal antibodies, cDNA probes for diagnostics, transgenic plants (potatoes), integrated pest management for crop protection, and raspberry and strawberry breeding programs.

6.a Patents, Technical Papers and Citations

Information on this subject is contained in the 1991 Agriculture Canada Research Branch Report, pp. 202-204. Thirty-two publications are listed, as well as nine Technology Transfer documents. All research publications are in refereed scientific journals. Information on citations was not available.

6.b Spin-off Companies

A virus-free seed potato industry in Pemberton has resulted directly from the potato research program at the station. The area has 19 virus free potato farms with approximately 500 acres under cultivation in total to produce about 6000 tons of potato seed annually. This crop is valued at approximately $3 million p.a. Potato yields are estimated to improve by up to 38% through the use of virus free seeds. Over 70% of seed potato production is sold in the U.S., with the rest sold domestically.

Nine cultivars of raspberries and five cultivars of strawberries have been released. These cultivars, especially the strawberries, dominate the industry and have had a major impact in B.C. and the U.S. Pacific North West in particular.

6.c New Products Resulting from Research

No estimates provided.

6.d Intangible Benefits

Research in the Vancouver laboratory has had a major impact on the diagnosis of diseases on plants coming into and going out of Canada (and other countries).

A number of local pest management companies, such as Crop Consult rely heavily on research at the Vancouver station.

6.e Outstanding Research Scientists Attracted to B.C.

Many of the scientists working in the Vancouver Laboratory could easily get jobs at major research centres around the world. Dr. Helène Sanfaçon, an expert in the molecular aspects of virus:host specificity (who joined the laboratory in 1990) received particular mention.

6.f Benefits to Provincial R&D Establishments

1. Twelve scientific staff members hold adjunct professorships at either U.B.C. or S.F.U. In 1990-91 there were nine graduate students working on-site on their theses under supervision from staff. In addition there were two post-doctoral fellows on-site.

2. The facility usually employs 5-8 summer students annually. Several have gone on to graduate research.

7. Important Collaborative Organizations

1. Work very closely with U.B.C. (Faculty of Agriculture, Depts of Botany, Microbiology and the Biotechnology Centre) and S.F.U. (Dept. of Biological Sciences). Collaboration with U. Vic. is developing.
2. Work closely with a number of Fraser Valley farm organizations to help solve current problems.
3. Receive funding from internationally oriented organizations for work related to African agriculture.

8. Suggestions on How B.C. Might Derive Greater Value from the Work at This Establishment

No suggestions made.

9. Industry Overview

1. Work on the genome sequencing of viruses has potential wide application to methods of controlling viruses by genetic engineering.
2. The laboratory focus is on the following agricultural products:

Small fruits:	Approximate B.C. Revenues
Raspberries	$30M. p.a. (2800 ha.)
Strawberries	$20M. p.a. (800 ha.)
Cranberries	$18M. p.a. (950 ha.)
Blueberries	$14M. p.a. (1000 ha.)

Blueberries are growing rapidly and expected to reach $28M by 1996.

Vegetables: (potatoes, carrots, lettuce, onions, asparagus) approximate annual revenue in B.C. in 1990: $109M.

10.a Recent Publications

The following documents are on file in the PACST library:

1. *Agriculture Canada - Research Branch Report - 1991*, 204 pp. Contains, amongst other information, a brief listing of the mandate, principal activities, scientists and publications for each of the 41 Agriculture Canada research facilities in Canada. Budgetary information is not included.
2. *Vancouver Research Station Overview - External Review and Advisory Committees Briefing Material*, December, 1990, by D.L. Struble, Director, 33 pp. This is not a public document. It does however provide valuable summaries of the research station's activities.
3. *Canadian Agricultural Research and Technology Transfer - Planning for the Future*, Part 9 of a series of working papers on Agriculture Canada Research Branch Strategic Directions, August, 1991, 23 pp. This document provides a valuable overview of the research mission of the department, and of its plans for implementation.
4. *History of the Vancouver Research Station*, - Agriculture Canada brochure dated 1986
5. *Progress in Research, Volume 11, 1990 and volume 12, 1991* - Annual survey of research in Agriculture Canada, about 28 pages for each edition.
6. "The Pemberton System" - A three page article by Edward R. Johnston which appeared in *Spudman*, pp.18,19 and 32, February, 1991; and a copy of a letter from Mr. Johnston (dated Nov. 22, 1991) enclosing a copy of a proposed follow-up article of similar length.
7. Agriculture Canada Merit Award - A three page description of the merit awards given to Dr.Norman Wright and his associates in connection with their development of virus free seed potatoes.

10.b Key Scientific or Technical Papers

A separate list was not provided; however the publications appearing in the relevant fiscal year are listed in the appropriate Research Branch report.

11. Major Projects

There are three major research groups at the station: entomology, plant pathology, and virus chemistry and physiology. Each group works at problems related to potatoes (8.4 PYs), other vegetables (20.8 PYs) and berries (20.8 PYs).

1. Entomology

The entomology group comprises eight research scientists and supporting staff.

Aphids have been the primary focus of study, both because of the crop damage they cause directly as well as the fact that they act as carriers for many viruses.

With the aid of computer models of population dynamics of aphids, it is possible to predict the arrival of aphic flights and thus accurately time biological controls or insecticide applications. Integrated pest management programs are being developed for cranberry, blueberry, strawberry, raspberry and vegetable pests with a view to improved efficiency and reduction of ground water contamination.

2. Plant Pathology

The plant pathology group comprises six research scientists and supporting staff. In more recent years it has become active in the development of new highly sensitive and specific probes for the detection of certain pathogens.

Monoclonal antibodies and complementary DNA probes are being developed for the detection of bacterial and viral diseases in potatoes, other vegetables, and berry fruit plants. In some specific cases methods have been developed for transferring specific genes from viruses to two of the hosts, potatoes and strawberries, in an attempt to develop virus-resistant plants. Breeding of raspberry and strawberry plants is also being done for improved quality, appearance, and adaptability to conditions in the Pacific regions.

3. Virus Chemistry and Physiology

The group comprises six research scientists and supporting staff.

In addition to the more traditional studies of viral transmission via infected eggs and pollen and the infection of otherwise resistant plants in the presence of other viruses, the virus-host interactions are now being studied at the cellular and molecular levels. The nucleotide sequences of several plant virus genes and proteins have been deduced. This has permitted, for example, the transfer of the potato S virus coat protein gene to the potato with the resulting transgenic potatoes being resistant to the virus. The effects of light on plant virus activity are also being studied, as well as the activity of some natural plant products to inhibit virus growth.

CHAPTER 5 - ENERGY MINES AND RESOURCES CANADA

5.1 General Overview

A comprehensive knowledge of the geoscience of Canada and its vast offshore area is fundamental to environmentally responsible economic development, public safety and national sovereignty. Acquiring, interpreting and making that information available to all Canadians is the mission of the Geological Survey of Canada, and has been since its founding in 1842. The GSC has carried out geological field work in B.C. since 1877.

The GSC has two scientific branches, the Geophysics, Sedimentary and Marine Geoscience Branch (of which the *Pacific Geoscience Centre* outside Victoria is a part), and the Minerals and Continental Geoscience Branch, (of which the *Cordilleran Division* in Vancouver is a part). With minor exceptions, the *Pacific Geoscience Centre* and the *Cordilleran Division* comprise the R&D presence of EMR in B.C.

The approximate size and budgets of the two facilities for 1991/92 were as follows:

Facility	Est. Annual Budget($000) Internal Funds	Person Years Scientists	Person Years Total
Pac. Geo. Ctr.	$5,123	16	42
Cordilleran Div.	$3,916	33	48
TOTAL	**$9,039**	**49**	**90**

Total intramural scientific expenditures by EMR appear to have been relatively fixed in the time period 1985/86 to 1989/90, oscillating between a low of about $280 million and a high of about $296 million. In 1991, internal funding appears to have increased to $341 million.[1] The 21% increase over 6 years will be less than the corresponding inflationary increase in the period.

The $9 million of scientific expenditures by the department in B.C. 1991/92 compares with overall intramural scientific expenditures by the Department of $341.0 million. This would put the Department's intramural expenditures in B.C. at approximately 2.7% of their total intramural expenditures. A ratio calculated on the basis of R&D spending alone, (i.e.

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[1]Source: Statistics Canada, *Federal Scientific Activities, 1990-91*, Cat. No. 88-204, p.26. This figure is ranked "preliminary" by StatsCan.

which excludes "related scientific expenditures") is shown in Table 2.4 on page 22. It would appear from Table 2.4 that B.C.'s share of gross Canadian revenues from mining and quarrying is 15.6%, while the share drops to 12.5% if petroleum and hydro resources are included. Hence there is a real asymmetry between Federal intramural expenditures on resource related R&D, and the share of those expenditures in B.C.. The fact is that all provinces except Ontario will in all likelihood experience a similar disproportionality, since 83.5% of the department's intramural expenditures on R&D take place in the National Capital Region on the Ontario side of the river.

5.2 Pacific Geoscience Centre, Geological Survey of Canada

Civilization exists by geological consent...subject to change without notice.

Will Durant, quoted in brochure about the Pacific Geoscience Centre

Overview

The *Pacific Geoscience Centre* (PGC) was established in 1978 in a wing of the Institute of Ocean Sciences near Sidney, B.C. Scientists at the centre are involved in broad-ranging geophysical investigations of the Pacific margin, and in monitoring earthquakes and variations in the Earth's magnetic field, mapping of the Earth's gravity field, and measuring the Earth's heat flow.

The Marine Geology Section of the Pacific Geoscience Centre also carries out geological mapping activities to provide geological information to support potential offshore resource evaluation and to contribute to environmental studies. Geoscience survey activity currently being undertaken includes Cordillera bedrock surveys, marine geological studies of Dixon Entrance and parts of the Strait of Georgia, and marine crustal studies of the Juan de Fuca Ridge.

The Environmental Geoscience Program includes installation of seismographic stations in western Canada, analysis of earthquakes in the region, preparation of seismic hazard maps, and studies of the subduction of the Juan de Fuca plate off the west coast of Vancouver Island, and of crustal deformation on Vancouver Island itself.

Many of these studies require ship time which is obtained from the Department of Fisheries and Oceans, and which has been an increasingly scarce commodity in recent years. Four years ago there were 12 to 14 cruises, two years ago there were nine, and last year there were six.

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2. Mandate/Objectives

The PGC conducts a wide range of geoscientific activities in the Pacific offshore and throughout the Canadian Cordillera, the mountainous region of Western Canada. Its primary responsibilities include the monitoring of earthquakes, evaluation of seismic risk and examination of seismic processes, conducting both systematic and specialized geophysical and geological surveys onshore and offshore, including those directed towards the identification of natural hazards, and studies related to the nature and distribution of natural resources both on and beneath the sea floor.

3. Budgetary Information

Year	Operating	Salaries (est)	Contracts	Capital	Total
1988/89	$2,275 K	$2,520 K	$800 K	$560 K	$5,355 K
1989/90	$2,500 K	$2,460 K	$875 K	$828 K	$5,788 K
1990/91	$2,050 K	$2,580 K	$720 K	$1,158 K	$5,788 K
1991/92	$1,809 K	$2,314 K	$630 K	$1,000 K	$5,123K

Comments:

1. Salary costs (including benefits) have been estimated by multiplying person years by $60 K except for 1991/92 when the exact figure was available. No correction for inflation was made.
2. Contracts for services have been estimated at 35% of the operating budget.
3. The A base operating budget has varied quite substantially from year to year, but the total operating budget has been smoothed by access to the Office of Energy R&D program which provided funds varying from $99 K to $136 K over the period, and by access to the Frontier Geoscience Program which contributed $1,377 to the operating budget in 1988/89 tapering off to just under half that amount in its last year, 1990/91.

4. Person years

Year	Research Scientists	Scientific Support	Admin.	Total
1988/89	18	19	5	42
1989/90	18	18	5	41
1990/91	17	20	6	43
1991/92	16	20	6	42

Comments:

About two thirds of the research scientists have PhD's, with the remainder at the Bachelors and Masters level.

5.a Principal Criteria for Success

The GSC as a whole has an external review committee made up of industry, university, and other government scientists. They periodically evaluate the scope, importance and utility of the research done at IOS.

5.b Most Successful Projects

1. The Fraser Delta project is a joint undertaking between three Geological Survey divisions and B.C. Hydro. The purpose is to look at the stability of the off-shore portion of the delta and to determine the sediment dynamics. This is important for the coal port, B.C. Hydro, B.C. Ferries and other users of the delta.
2. The recent work on the role of hydrothermal fluids in mineral deposition of sedimented spreading ridges has led to new models of mineral deposition that may have significant economic import on exploration in older, volcanic environments of a similar nature on land.
3. Recent work combining heat flow data, deep seismic reflection data, and electromagnetic data have led to a better understanding of the processes associated with the Cascadia subducting plate. The tectonics associated with the subduction process determines the likelihood of large earthquakes resulting from the brittle portion of the plate sticking to the North American plate. The recent work provides estimates of the zone where the plate is brittle, and also where this zone is located relative to Vancouver Island.

6.a Patents, Technical Papers and Citations

List of publications or citations not readily available. Each scientist maintains an individual list of publications.

No patents were mentioned.

6.b Spin-off Companies

None listed

6.c New Products Resulting from Research

None listed.

6.d Intangible Benefits

The Pacific Geoscience Centre performs a variety of essential public services, such as operating the Tsunami warning system, and monitoring and analysing earthquakes.

The long term research related to plate tectonics provides us with an understanding of the processes at work in shaping and shaking our land mass, while research on the Juan de Fuca Ridge opens the door to a better understanding of the causes for concentrations of minerals and metals in some locations. Geomagnetic and gravity surveys are important tools in the search for minerals and petroleum resources.

6.e Outstanding Research Scientists Attracted to B.C.

Dr. E. Irving, paleomagnetist and one of the original scientists involved in plate tectonics. Dr. Irving came to B.C. from Ottawa about 10 years ago.

At any given time there are likely to be one or two distinguished scientists visiting the centre.

6.f Benefits to Provincial R&D Establishments

The Centre has been involved in working with the University of Victoria in the establishment of its Centre for Earth and Oceans Research, under the leadership of Dr. Chris Barnes, an Director General of the GSC. Centre scientists also work with scientists at Royal Roads, at the Defence Research Establishment, Pacific, at U.B.C. and, to a lesser extent, with S.F.U.

7. Important Collaborative Organizations

See response to 6f above.

8. Suggestions on Ways B.C. Might Derive Greater Value from the Work at This Establishment

No strong suggestions came to mind, but there was some thought that the Provincial government might want to have a greater involvement in earthquake research, as well as with the PGC near shore and coastal environmental studies, such as the study of the Fraser delta.

9. Industry Overview

PGC's research supports the minerals and petroleum industry. In practice more detailed studies related to mineral exploration are undertaken by geologists at the Cordilleran Division in Vancouver.

As described in the response to 6d above, the Centre is more involved with providing support to the public sector as a whole, than in support for particular segments of the private sector.

10.a Recent Publications

The following materials were provided by the Centre, and is stored in the PACST library.

1. *The Pacific Geoscience Centre* - A 16 page glossy booklet describing the activities of the Centre (1991).

2. *Long Term Strategic Plan, The Geological Survey of Canada* - A 33 page strategic plan for the Geological Survey. The document is undated, but covers the years 1991/92 to 1995/96. The activity is broken out into Geoscience Survey, Minerals Program, Energy Program, Environmental Geoscience and Geoscience Information. Overall funding plans are given, and an appendix lists a number of planned projects by year of initiation or finish. In general, the information provided is not broken down by province.

3. *The Geological Survey of Canada, Annual Report, 1991 - A 28 page report with useful general* information.

4. *The Pacific Geoscience Centre* - A short brochure.

10.b Key Scientific or Technical Papers

None given.

11. Major Projects

The following ongoing projects for 1991/92 were listed:

Geoscience Survey Program (about 20 person years)

1. Cordillera Bedrock Surveys - investigate fossil ichthyolith biostratigraphy, thermal maturation and paleo-environmental geochemistry.

2. Carry out a regional gravity survey over a large region of the Yukon, and obtain gravity profiles in the Bowser Basin to assist geophysical modelling.

3. Continue geomagnetic studies of Quaternary stratigraphy and of Cretaceous plutons across the coast belts

4. Carry out geophysical modelling of the Bowser Basin using new high resolution gravity profiles and analysis of rock density and magnetic susceptibility.

5. Determine the porosity of the sea floor sediments for the Fraser Slope using a newly developed sea floor electromagnetic system.

6. Study the production, distribution and movement of methane gas in the shallow sediments and overlying water column of Bute and/or Knight Inlet in co-operation with the Institute of Sedimentary and Petroleum Geology and the University of Victoria.

7. Continue geological studies of Dixon Entrance and northern Hecate Strait.

8. Obtain sedimentation rates and dynamics of Georgia Strait - Fraser Delta with ^{137}Cs.

9. Continue with a variety of crustal studies, including the Ocean Drilling Program in Middle Valley of Juan de Fuca Ridge, determination of the structure and origin of contained methane hydrates, ocean drilling off Vancouver Island, and petrological studies of various provincial lavas.

Environmental Geoscience Program (14 person years)

1. Install new digital Canadian National Seismic Network stations in western Canada, and locate, catalogue and analyse earthquakes in western Canada. Prepare seismic hazard maps.

2. In conjunction with Scripps and JPL conduct the fist phase of a marine geodesy experiment off the west coast of Vancouver Island to look at relative motion as the Juan de Fuca Plate subducts beneath the North American plate. Establish permanent GPS trackers at Penticton and Victoria.

3. Continue study of local stability of Canadian very long baseline array sites, and of the crustal deformation on Vancouver Island.

4. In co-operation with other GSC Divisions and with B.C. Hydro, obtain geophysical data and geological sampling of the Fraser Slope area.

5.3 Cordilleran Division and Vancouver Office

Overview

> *And some rin up hill and down dale, knapping the chucky stanes to pieces wi' hammers, like sa mony road-makers run daft. They say 'tis to see how the world was made!*
>
> From Sir Walter Scott, reproduced in the Cordilleran Division, GSC Calendar, 1992

As the Director of the Cordilleran Division, Dr. Tempelman-Kluit put it, the role of geology in its resource application is analogous to providing a map of a supermarket's aisles and shelves, so that when desired a searcher can go directly to the shelf where, for example, the beans (or copper and gold) are. The profession is a long way from reaching that stage of precision in the search for gold and other minerals, but steady progress is being made.

1992 marks the 150th year to the Geological Survey of Canada, and the 75th year of its presence in Vancouver. The GSC has carried out geological field work in B.C. since 1877. The Cordilleran Division sees its role primarily as the provider of the fundamental information about the geology of the Cordilleran Region (comprising most of B.C. and the Yukon, about 10% of Canada's land mass), which those who explore for minerals or energy resources will use to decide where to conduct their search, and which are used by development planners to assess and minimize environmental impacts. These data are further interpreted in terms of hazards to human health and development.

The maps and supporting documents produced by the division are designed to provide a broad scale three dimensional overview of the land and adjacent underwater terrain. It is critical to the success of this endeavour to have an understanding of the changes to the land mass over geological time, hence a major focus of research activity is to determine the age of minerals accurately. The Division has played a leading role in developing techniques for identifying the age of the prevalent sedimentary rock in the region (which dates largely from the Triassic period (260-210 million years ago)), particularly through the technique of examining the ubiquitous Conodont fossil samples which underwent substantial evolutionary change over the Triassic period.

The precise level of employment at the Vancouver office is dependent on the season, but there is a base of about 48 full time staff, 33 of whom are scientists. Four of the scientists in Vancouver are actually employed by a sister division and report in to Ottawa. The Cordilleran Division has been enlarged since 1988 by about 10 person years.

While the main activity of the division is the production of geological maps and the conduct of the research which underpins it, the division also runs a sales outlet for maps and related documents from its Vancouver location. Sales are roughly $250 K p.a., and include sizeable sales related to recreational use of the land (hikers, campers etc.). The library of the Division contains some 100,000 volumes and is open to the public. Last year visitors spent about 3000 person days at the library.

It is estimated that there are approximately 5000 people in the Vancouver area involved in mineral exploration. These people comprise the primary client base of the research group. The division works closely with its provincial government counterparts in attempting to service their needs. The B.C. and Yukon Chamber of Mines is the primary industry representative group with whom they communicate.

While explorationists are the prime client base for the division, it also has important data on water and rock quality, since, as a part of its ongoing work, it systematically measures the metal content of sediment and water in streams, rivers and lakes. For example, data collected by the division (and made publicly available) was used to determine that the uranium content in the water consumed by residents of Atlin, B.C. was above tolerance levels, and appropriate steps to change the water supply were taken.

The division believes it has played a major role in many of the new exploration initiatives undertaken in B.C. One recent example is activity in the Wolverine complex, which was fostered by theories of the formation of the Caribou plateau developed by researchers in the division. Another example is in Northern B.C.'s Iskut region, where new data on the mineralization determinants indicative of gold occurrences have focussed exploration activity.

Links with the universities, particularly the Geology Department at U.B.C., appear to have been good and appropriate. Dr. Tempelman-Kluit expressed some concern that the Geochronology Laboratory, formerly run by Professor Armstrong at U.B.C. is apparently no longer operating. He indicated that this was a significant loss to "the whole community". There appears to be a good working relationship (fortified by mutual respect) with the Geological Survey Branch of the Ministry of Energy, Mines and Petroleum which focuses on detailed geological maps of areas of particular current mineralogical interest.

The division is proud of its accomplishments and of its distinguished history. It is believed that much is owed to the relative stability it has enjoyed relative to its sister organizations in the U.K., New Zealand and, to a lesser extent, in the U.S. Links with the geophysics community, and in particular

with the Pacific Geosciences Centre in Sidney, seemed to be surprisingly weak. Apparently there is an industry wide problem of obtaining good collaboration between geologists and geophysicists. The GSC would appear to have been no more successful at bridging the gap than others.

1. **Address**

4th Floor, 100 West Pender Street, Vancouver, B.C., V6B 1R8

Contact

Dr. D. Tempelman-Kluit, Director

TEL: (604) 666-0529 FAX: 666-1124

2. **Mandate/Objectives**

The Cordilleran Division is responsible for gathering, interpreting, synthesizing, reporting on, disseminating, and promoting the use of all earth science data for the Canadian Cordillera. Division staff will collaborate with experts of all appropriate disciplines. The object is to gain an understanding of the Cordillera for the benefit of all Canadians in resource utilization, environment management and hazards mitigation applications.

3. **Budgetary Information (thousands of $)**

Year	Operating	Salaries	Capital	Total
1990/91	$1,602	$1,905	$275	$3,782
1991/92	$1,662	$1,999	$255	$3,916

Comments:

1. While data for other years were not supplied, funding of the operating budget was roughly at the $700K p.a. level up to 1988, when it was boosted to about $1.8 million for work in the Queen Charlotte Islands as a part of the Frontier Geoscience Program. Subsequent to the termination of this program in 1990, funding has declined only slowly (at a rate of about 4.5% p.a.).

4. **Personnel - Vancouver Office**

Year	Research Scientists	Scientific Support	Admin.	Total
1991/92	33	3	12	48 perm
	+6	+15		+ 15 temp.

Comments:

1. A new development in 1992 is that, as part of a total Federal government initiative, the Survey is responsible for a salary budget as well as a person year budget. The salary budget for 1992/93 is expected to be about $1.9 million. All of those listed above work for the Cordilleran Division except for four research scientists who report to divisions in Ottawa.

2. Of the 18 scientific support staff, only 3 hold full time positions. It has been office practice to employ graduate geologists for terms of three to six months during the winter season to assist with data interpretation.

3. The twelve administrative personnel include five persons involved with operation of the library and sales of publications.

3. The person year complement represents an increase of about ten persons over that of five years ago. The increase came about at the time of the initiation of the Queen Charlotte Islands project as a part of the Frontier Geoscience Program.

4. In addition to the paid employees, there are four "*researchers emeriti*", who continue to work with the Division on an unpaid basis as well as two postdoctoral fellows who are supported by NSERC.

5. The Division typically employs about 35 summer students to assist with the field work.

5.a Principal Criteria for Success

Criteria of success are based on successful on-time achievement of objectives as predetermined for each project as a part of the annual planning process. The principal objective is to provide quality geological maps (and associated publications) of areas of interest to the mineral exploration community.

While the number and quality of scientific publications is important to the promotion prospects of the individual research scientists, it is only one of the important performance criterion for the Division as a whole.

5.b Most Successful Projects

1. The Division has just released a large scale geological map of the Cordillera (about 10% of the area of Canada), complete with extensive supporting explanatory documentation. This is the culmination of a ten year project led by Dr. John Wheeler, who is now an Emeritus Research Scientist. The Division believes that it is the best geological map of its kind to be found in North America.

2. The Queen Charlotte Islands project which started in 1988 was completed in 1991, and includes some 58 geological maps of both land surface and underwater terrain. Papers by some 42 participants have been published with the maps.

This work built on previous excellent maps produced by the province, and considerably advanced the state of knowledge of the area. In the light of the subsequent designation of a substantial land area in this region as a future national park, the immediate utility of this information is less than anticipated, but it has been used by the Haida and by Parks Canada.

3. The Cordilleran Division has doubled its output over the past three years to some 47 contributions to current activity, or about 30% of the output for all of the GSC.

6.a Patents, Technical Papers and Citations

Patent applications are minimal, and no records are kept.

The Division publishes a substantial (the most recent volume contains 377 pages) annual compendium of papers on its research activities, which includes references to papers in refereed journals.

6.b Spin-off Companies

No major examples came to mind, but there are a number of small companies. One example is C F Minerals in Kelowna, which analyses Conodont samples to help determine the age of the rocks in which the samples are found. This is a technique in which the Division has played a leading developmental role, and which has been successfully applied to determination of the age of many strata throughout the Cordilleran Range.

6.c New Products Resulting from Research

Information supplied by the Division is believed to have been an important, if not an essential, contributor to the discovery of many mines in B.C., but it is difficult to be specific.

6.d Intangible Benefits

Most of the benefits have been intangible, in that it has played an important role in the exploration leading to B.C.'s roughly $4 billion annual revenues from mineral production.

In addition, the division is the best source of data on the mineral content of water supplies throughout the province, thereby providing both a valuable baseline for pollution measurements, and, on occasion, important information more directly related to human health, as in the case of its finding of dangerous quantities of uranium in the water used in Atlin, B.C.

6.e Outstanding Research Scientists Attracted to B.C.

At any time, there are three or four visiting scientists from around the world resident with the Division, which has an international reputation for its expertise on the Cordillera.

6.f Benefits to Provincial R&D Establishments

Links to U.B.C. are the strongest due to the existence of a Department of Geology. Curiously, only one division scientist is an adjunct professor there (vs four at SFU).

Twelve staff are currently teaching courses at U.B.C. (none of whom are adjunct professors).

Some research is contracted to B.C. universities, but this is not extensive (estimated at about $70K). In addition, the division supports the field work related to a number of graduate theses, and is currently supporting two post-doctoral fellows.

The division employs about 35 summer students, most of whom come from Western Canadian universities.

7. Important Collaborative Organizations

The most important collaborating organization is the B.C. Geological Survey. Whereas the GSC endeavours to provide broad background information to those prospecting for minerals, the Geological Survey Branch endeavours to be more responsive to needs for more detailed information on areas of particular current interest.

Links to the Geological Survey departments in other countries appear to be weak.

8. Suggestions on Ways B.C. Might Derive Greater Value from the Work at This Establishment

No dramatic or strong suggestions. On-going collaboration with the B.C. Ministry of Energy, Mines and Petroleum Resources at many levels is important and is currently satisfactory.

9. Industry Overview

Vancouver is a world centre for mineral exploration, with some 5,000 experts based in B.C. The division provides vital support to this group insofar as its activities are focussed on the Cordillera. Unlike the French government (which is almost unique in this respect), the Geological Survey of Canada does not support geological survey work desired by Canadian exploration companies outside of Canada.

It is estimated that expenditures on mineral prospecting in B.C. were approximately $190 million in 1990. Since 1987, the estimates have ranged from a low of $150 million in 1989, to a high of $215 million in 1988. In 1986, the corresponding figure was only $91 million. Favourable tax treatment for exploration activities introduced in that year had a rather dramatic positive effect.

10.a Recent Publications

The following material is now on file at PACST:

1. *Geological Survey of Canada Annual Report, 1990-91* An overview of the whole department, of which the Cordilleran Division accounts for 3.5% in budgetary terms (the Pacific Geoscience Centre accounts for a further 5.2%).

2. *Cordilleran Division Project Inventory, 1990-91* (dated Sept. 10, 1990) A sixteen page typed document listing 50 projects in various stages of completion. As well as a brief description and the name of the principal investigator, a record of 1990 operating

expenditures, and the number of journal papers, abstracts and theses produced are recorded.

3. *Current Research, Part A - Cordillera and Pacific Margin, Paper 92-1A*, a 377 page collection of 47 papers reporting on the Division's research in the 1990-91 time frame. This is the most recent of an annual series of publications.

4. *Geology and Canada*, a 32 page tutorial on Canadian geology.

5. *GEOS, vol.20, no.3, Summer, 1991*, an edition devoted to the important role of paleontology in determining the geological history of the Cordillera. This journal provides a good overview of the 'theoretical' research of the division which underpins the production of its maps.

6. Miscellaneous pamphlets and a calendar which provides interesting historical glimpses.

10.b Key Scientific or Technical Papers

A listing of publications emanating from the Cordilleran Division for the period April 1, 1990 to March 31, 1991 is on file in the PACST library. It includes 21 refereed publications and over 80 current research reports. Work on geological dating using conodonts has been of particular significance in recent years.

11. Major Projects

Information was not readily available in this form. See under question 5b for information on major recent projects. More detailed information is contained in the material on file listed in the response to 10a above.

CHAPTER 6 - ENVIRONMENT CANADA

6.1 General Overview

It is sometimes a little difficult to track the organizational chess which is played by the government, and Environment Canada is surely a case in point. A department of fairly recent origin, it has nonetheless, in its time swallowed and subsequently regurgitated parts of Fisheries and Oceans Canada and all of Forestry Canada. The Canadian Wildlife Service, once an independent entity, is now a part of the Conservation and Protection Branch of the department, the other major operating branches being the Atmospheric Environment Service and the Parks Service.

The approximate budgets of the research activities of the Conservation and Protection (including both CWS and Environmental Protection) and Atmospheric Environment Service branches in B.C. for 1991/92 were as follows:

Facility	Est. Annual Budget($000) Internal Funds	Person Years Scientists	Person Years Total
Cdn. Wildlife Svce.	$1,520	12	18
Env. Protection	$600	0	10
Atmos. Env. Svce.	$800	0	7
TOTAL	**$2,920**	**12**	35

While virtually the only research activity of the department in B.C. is that associated with the Canadian Wildlife Service, both the Atmospheric Environment Service and the Environmental Protection Division are involved in a commendable amount of contracting out and technology transfer.

The *Parks Service*, the western arm of which is headquartered in Edmonton, does little scientific research except in the field of restoration of cultural materials and historic sites, none of which is currently managed out of B.C. The Atmospheric Environment Service has its major research facility (of about 200 people) in Downsview, Ontario, but does have a low level research activity in Vancouver which is reported on below.

Only the *Conservation and Protection Branch* does research of any substance in B.C., almost all of which is performed by the *Canadian Wildlife Service* and is related to migratory birds. The migratory bird research is centred at the Reifel Bird Sanctuary.

In addition to their work with migratory birds, the core research of this group is directed towards understanding coastal and estuary systems (particularly those under the constant threat of change), and environmental toxicology.

The group is particularly proud of its contributions to the ecology of old growth forests as it bears on forest birds, of its early studies of the effects of dioxins on herons, of its decade long studies of sea bird colonies, and of its studies of waterfowl and their habitat which have been of great value in understanding some of the effects of civilization's advance into the wetlands, particularly the Fraser River estuary.

Environmental Protection, also a part of the Conservation and Protection Branch, plays a role which is primarily investigative and regulatory. It does not itself perform any research, but is a major user of other people's research results and other department's research programs. The Division's Director estimates that between 10% and 20% of the effort of the division is directed towards science based recording activities and the brokering of commercial development projects amongst the various agencies which fund R&D. A notable example of this latter activity is the development if the BIO-P sewage treatment process which was first put into use in Kelowna.

The *Atmospheric Environment Service* (AES) does not do formal research in Vancouver. Those activities take place at AES's research facility in Downsview, Ontario. However, the Vancouver office is active in some applied research and development activities and have enjoyed considerable success, albeit on a modest scale.

Since most of B.C.'s weather approaches from the Pacific Ocean, where weather observation posts are sparse, the group have become experts at interpretation of satellite information. This enforced interest has led to their playing a prime role in the development of some very successful data analysis tools, most notably the Metdas system, contracted to MacDonald Dettweiler and Associates, using the now defunct Unsolicited Proposal Fund. It has also led to some better techniques for forecasting marine weather, especially the dangerous rapidly developing storms, on which considerable progress has been made. The group is seeking funding to finance development of an expert system to encapsulate some of the specialist knowledge needed for correct interpretation of data in order to make good forecasts.

The Green Plan is an important new development. Announced about a year ago, and planned for execution over six years (an extension from the originally announced five year time frame) at a cost of over $3 billion, it includes substantial funding for research, including a $250 million Science

and Technology Action Plan administered by Environment Canada out of the office of the Science Advisor in Ottawa. Very little of this money has been expended to date, since the program is only just getting up and running.

7.2 Canadian Wildlife Service, Pacific & Yukon Region

Overview

In 1916, Canada and the U.S. signed the *Migratory Birds Convention*, and the following year Parliament passed legislation requiring the Federal government to take responsibility for the management of certain species of migratory birds. In 1973 the *Canada Wildlife Act* was passed enabling the government to carry out wildlife research and, in co-operation with the provinces, to undertake a wide range of wildlife conservation and interpretation activities for "any non-domestic animals or their habitats".

B.C. has the highest number of wintering birds in Canada, and the highest diversity of all birds and all wildlife in Canada. The Canadian Wildlife Service has been conducting research in B.C. since the 1940's. Although the service has responsibility for some mammal populations as well, in practice, the B.C.-based research efforts have focussed almost exclusively on birds.

Research in B.C. is based at the Alaksen Natural Wildlife Area (Reifel Bird Sanctuary). Currently the research group comprises 18 people, 12 of whom are scientists. The laboratory expects of have a complement of 22 people within a year. Research work focuses on eco-systems. The scientists endeavour to stay away from species specific research. Notwithstanding, the Service is responsible for treaty obligations with respect to certain migratory birds. The group is also heavily involved in research related to the Fraser River Estuary.

Major successes of the group include pioneering dioxin work on blue herons which alerted the B.C. community to dioxins in local waters and in fish; inventories and research of sea bird colonies which have led to an understanding of the implications of oil spills and driftnet fishing on sea birds; and Fraser estuary (in particular) surveys and research which has enabled intelligent planning of development in such a way as to minimize the impact on waterfowl and shorebirds.

The Canadian Wildlife Service in B.C. is also responsible for management of the Environment and Protection Service Regional Laboratory in West Vancouver, a 16 person-year facility which conducts a variety of inorganic and organic analyses, some of which are related to legal prosecutions of oil spills and other unauthorized discharges.

1. **Address**

P.O. Box 340, Delta, B.C. V4K 3Y3
(5421 Robertson Road, Westham Island)

Contact/Title/Telephone/Fax

Dr. Art Martell, Director
Dr. Steve Wetmore, Chief, Ecosystems Evaluation and Research

TEL: (604) 946-8546 FAX: 946-7022

2. **Mandate/Objectives**

The Canadian Wildlife Services (CWS) Directorate carries out basic and applied research on wildlife and ecosystems structure and function to fulfill mandates under the Migratory Birds Convention Act, Canada Wildlife Act, Fisheries Act, and the Canadian Environmental Protection Act.

In general, the research deals with migratory birds, habitat, wildlife of national interest, international wildlife and toxics. The work of the Service involves study of coastal ecosystems, forest ecosystems, critical habitat and threatened ecosystems, endangered species and their habitats, caribou, migratory birds, wildlife toxicology and health and biometrics.

3. **Budgetary Information (in thousands of dollars)**

Year	Operating	Est. Salaries	Ext. Rev.	Capital	Total
1989/90	$250	$750	?	$40	$1,040
1990/91	$270	$800	?	$45	$1,115
1991/92	$395	$1,040	?	$85	$1,520
1992/93	$1,210	$1,200	$742	$48	$2,458+
1993/94	$1,426	$1,430	?	$77	$2,933

Comments:

1. About half the operating budget is expended on outside contracts such as boat charters, aircraft rental and small university projects.

2. The Service handles contracts estimated at close to $1 million p.a. largely employing funds from other budgets. Contracts valued at approximately $600 K p.a. related to the Fraser estuary are let primarily with universities and consultants. A further $300 K - $500 K p.a. of contracts are let for more general purposes related to environmental protection and inland waters.

3. Following very large budget cuts in 1984, the research effort has grown slowly but steadily, and has now returned to its pre-1984 strength. Increased funding in 1992-1994 time frame is largely due to Green Plan support which in 1994 will support 7 person years above the base operating level, and provide increased operating funding of just over $1 million. CWS are the program managers for

the water quality research as a part of the Fraser Basin Action Plan. The major increase in operating funds is for contracts related to this activity.

4. The external revenue shown for 1991/92 is an "estimated value of contribution" and includes contributions in kind as well as direct funding. The largest contributors in this category were: The U.S. Fish and Wildlife Service ($225 K); Indian and Northern Affairs ($131 K); U.B.C. ($100 K); Forestry Canada ($80 K); University of Wyoming ($45 K) and B.C. Waste Management ($40 K).

5. Budgetary figures above exclude the activities of the West Vancouver Laboratory which is not involved in research, but is a "related scientific activity". Its task is to carry out a variety of inorganic and organic analyses, a significant fraction of which are related to water toxicity. The laboratory employs about 16 people and has an annual budget of about $1.3 million. The construction of a new $14 million laboratory to be located in North Vancouver has been approved. It is anticipated that it will be built within the next three years.

4. Person years

Year	Research Scientists	Scientific Support	Admin.	Total
1989/90				13
1990/91				14
1991/92	12	2	4	18
1992/93	13	3	5	21
1993/94	13	7	5	25

Comments:

It is estimated that scientists spend about 80% of their time conducting research, with the remainder devoted to public information and internal organizational activities.

One scientist (a specialist in sea birds) is permanently stationed at the Institute of Ocean Sciences outside Victoria.

Person year increases since 1991/92 result from support from the Green Plan, which is scheduled to reach 7 person years in 1993/94.

5.a Principal Criteria for Success

The research program is targeted primarily at discharging Canada's treaty obligations with respect to migratory birds and coastal estuary systems, with priority on the preservation of endangered species. Hence the prime criterion of success is measured in terms of conservation of wildlife.

Scientific publications are viewed primarily as a method of obtaining and maintaining the necessary scientific credibility which enables the Service to do its work of wildlife preservation.

5.b Most Successful Projects

Major successes include:

1. Research in forest birds has given the Service a strong voice in provincial deliberations concerning forest utilization.

2. Path breaking work on the effects of dioxins in Blue Herons uncovered the increasing amounts of dioxins in B.C. waters and led directly to dioxin investigations by the Department of Fisheries and Oceans, which in turn led to some fisheries closures.

3. Inventories and studies of sea bird colonies over the past decade have led to the development of strategies and action plans for the preservation of these birds in the event of oil spills. These same studies have been a source of useful knowledge in the assessment of the effect of drift net fishing on sea birds, and have buttressed legal action seeking restoration after oil spills.

4. Surveys and research on waterfowl over the past 30 years has enabled the development of proposals for restoration of wetlands, especially in the Fraser estuary. The research provided the scientific foundation on which Treasury Board approved funding for a U.S. $1 million Canada/U.S. Pacific Coast Wildlife Joint Venture, and was an important component in the approval of a $100 million Fraser River project, $12.5 million of which is directed at waterfowl conservation.

6.a Patents, Technical Papers and Citations

No.

6.b Spin-off Companies

No.

6.c New Products Resulting from Research

None that they are aware of.

6.d Intangible Benefits

Important changes in public awareness, in wildlife conservation and in improvements to the environment as detailed elsewhere.

Research in co-operation with the B.C. Dept. of Agriculture and U.B.C. has led to modified agricultural techniques, such as the introduction of different winter cover crops.

6.e Outstanding Research Scientists Attracted to B.C.

Strong links with Russia have been developed as a result of co-operative work on preservation of the Lesser Snow Goose, and Russian scientists are frequent visitors.

Two Wildlife Ecology CWS/NSERC chairs are being established at SFU. These chairs will focus on coastal ecosystems, and will enhance expertise in behavioural ecology and physiological ecology in the province. (Chair candidates are from outside B.C.)

6.f Benefits to Provincial R&D Establishments

Co-operation with provincial government authorities is warm and productive. Work with the universities, especially U.B.C. and Simon Fraser is very fruitful. Two to four summer students are hired each year, and several graduate students and post doctoral fellows collaborate with CWS scientists.

7. Important Collaborative Organizations

The CWS collaborates with a number of Federal and Provincial government departments, with the U.S. Fish and Wildlife Service, and with universities on both sides of the border. These collaborations are an essential feature of work on migratory birds.

8. Suggestions on Ways B.C. Might Derive Greater Value from the Work at This Establishment

The Service would like to see:

1. Funding available for the hiring of summer students.
2. More complementary initiatives with the universities.
3. A fund available to the research group specifically earmarked for university funding.

9. Industry Overview

Not applicable.

10.a Recent Publications

The following documents were supplied and are filed in the PACST library:

1. *Focus on the Canadian Wildlife Service* - A short brochure which outlines the history and programs of the service.
2. *Pacific Coast Habitat: A Prospectus* - A 27 page booklet describing the Canada/U.S. "Pacific Coast Joint Venture", a part of the overall "North America Waterfowl Management Plan".
3. *Report on Canadian First Step Projects for the 1988-1990 Period* - A 24 page booklet describing the first seven Canadian projects undertaken as a part of the North American Waterfowl Management Plan. None of these projects is in B.C. (The Pacific Coast Joint Venture described in 2 above, goes some way to remedying this deficiency.)
4. *A Wildlife Policy for Canada* - A 29 page booklet published in 1990 setting out policies adopted by federal and provincial ministers at a meeting in September, 1990.

5. *Canada and the RAMSAR Convention* - An 11 page departmental publication produced in 1987 describing Canadian activities in connection with this international convention (Ramsar is a place in Iran). Of 17 designated Ramsar Canadian sites, one Alaksen (Reifel) is in B.C., six are in the North West Territories.

6. *Lesser Snow Goose* - A 4 page brochure describing the Lesser Snow Goose published by the Canadian Wildlife Service in 1987.

10.b Key Scientific or Technical Papers

No list provided.

11. Major Projects

The following are six major current projects:

1. Waterfowl Use of Boundary Bay and the Fraser Estuary

This research is aimed at determining the dependency of waterfowl on Boundary Bay and adjacent agricultural lands, and hence being in a position to understand the potential impact of proposed agricultural land and wetland alternatives. The study was started in about 1960 and has been revived at various times as the need arises. The current three year program is scheduled for completion in 1992 at a total cost of about $300 K.

As population pressure increases in the Boundary Bay area, it is increasingly important to understand the effects of these pressures on wildlife.

2. Snow Geese Studies

The research explores the relationship between goose population dynamics and foraging habitat in the Fraser River Estuary. This is a five year project with expenditures of $100 K p.a.

3. Conservation Planning for Waterfowl and their Habitat

Research has focused on the effects of lead poisoning in waterfowl and raptors. The results have been used to establish some of the first zones in Canada where the use of non-toxic shot is mandatory. This is a five year project with expenditures of $20 K p.a.

4. Industrial Contaminants in the Strait of Georgia

This project is aimed at understanding the fate and effects of dioxins/furans in coastal ecosystems. The information is used to monitor the efficacy of pulp mill effluent changes and regulations, and for the management of coastal resources.

This is an on-going project with expenditures at the $150 K p.a. level.

5. Bio-Diversity in Old Growth Forests

This research is aimed at understanding the relationships between biodiversity, migratory bird populations and coastal old growth forest. The results are being integrated into forest management decision making and result in modifications to cutting practices.

6. Marbled Murrulets

Research is into the distribution, abundance and behavior of this threatened species in old growth forests and at sea in coastal waters. Information is used for species conservation planning. The project is currently planned for three years at an expenditure level of $100 K p.a.

6.3 Environmental Protection: Pacific And Yukon Region

Overview

Environmental Protection is part of the same division as the Canadian Wildlife Service and Inland Waters. In British Columbia, overall responsibility for the conduct and management of research has been given to the Director of the Canadian Wildlife Service. As already mentioned, the management of the Environment and Protection Service Regional Laboratory in West Vancouver, of which this group is the major user, is managed by the Director of CWS. This 16 person year facility is not, however a research facility, but rather conducts a variety of organic and inorganic analyses, some of which are related to legal prosecutions for unauthorized discharges and oil spills.

Environmental Protection finds itself continually called on to set new pollution standards in the absence of reliable scientific data. As one employee expressed it, "We typically have to decide on standards within twelve months when the necessary research to determine what ought to be done will take five years." This has led the group to spend a substantial fraction of their time searching the scientific literature and working with industry to find solutions to particular problems. In this latter endeavour, they often work closely with the developers of solutions to environmental problems to help find them development funding from a variety of extra-departmental sources. All told, they estimate that the equivalent of seven person years of the group's time is spent in such endeavours.

One of their greatest success stories concerns the assistance they gave to the City of Kelowna who wished to work with a UBC professor and consultants to install a biological sewage treatment system for removing phosphorus and nitrogen. With the help of the Unsolicited Proposal Program the group successfully developed and installed their BIO-P process, thereby saving the City of Kelowna about $36 million. This process has now been installed in several other interior cities and towns, as well as in the U.S., Denmark, and Australia. The market for this system is still growing, and two B.C. consulting firms are heavily involved in its development.

1. **Address**

224 West Esplanade, North Vancouver, V7M 3H7

Contact

Dr. J. Brian Wilson, Regional Director (666-0064)
Mr. Fred G. Claggett, Policy Advisor (666-6262)

FAX:666-7463

2. **Mandate/Objectives**

Environmental Protection is part of the Conservation and Protection Branch of Environment Canada. Its mandate involves the regulatory aspects of pollution prevention and control. As such, it does not perform research, but it does have a data gathering role, especially dealing with toxic chemicals.

The Branch is directly involved in technology development and transfer, operating as a regional arm for national programs. Among the programs in which it is involved are DRECT (energy related pollution control technology demonstration), DSERT (demonstration of site remediation technology), and two components of the GREEN PLAN Technologies for Solutions (Technology Commercialization Program and Technology Transfer Program). These two programs are conducted jointly with the Department of Industry, Science and Technology and the National Research Council.

3. **Budgetary Information**

There is no separate budget for research, nor are there research scientists on staff. It has been estimated that the equivalent of ten person years are involved in development activities with industry. This has been arbitrarily costed at $600K.

Budgets for the technology development programs referred to above are administered centrally based on the merit of proposals received. Most of the funds available are related to the Green Plan.

4. **Person years**

As previously mentioned, there are no scientific staff in the division. Currently the division has a staff of approximately 70 persons. It is anticipated that this number will rise to 90-100 persons as the Green Plan goes into the implementation phase.

It is thought that on average 10%-20% of the time of division personnel (or the equivalent of 7-14 py's) is taken up with scientific data collection and technology transfer activities. Departmental personnel play an important technology brokerage role. Additional information on the nature and dollar value of this activity was not available.

5.a Principal Criteria for Success

The Division endeavours to ensure that worthwhile projects which have been referred to it encounter a suitable funding mechanism, either federal or provincial.

5.b Most Successful Projects

The BIO-P project at the City of Kelowna Sewage Treatment Plant has achieved the greatest international marketing success. This is a project in which the City of Kelowna took a lead, and Environmental Protection worked with DSS to obtain development funding through the Unsolicited Proposal Program. Kelowna at the time (1978) was faced with the choice of a $44 million traditional sewage treatment process, or adapting a biological treatment process used with only moderate success in South Africa for use (in the very different climatic conditions) in the Interior of B.C. (as proposed by U.B.C. professor Bill Oldham). The cost of this alternative was only $12 million. The proposed development was successfully undertaken, and similar systems have now been installed in Westbank, Penticton, Montana, Denmark, Australia and possibly soon in Sweden. Two B.C. consulting companies are involved in this business.

Other successful development projects include sludge stabilization projects at Salmon Arm and Ladysmith, CTMP pulp mill effluent treatment using anaerobic processing at Quesnel, and making snow using sewage effluent (Kamloops).

6.a Patents, Technical Papers and Citations

Patents reside with the technology developer, and not with the department.

6.b Spin-off Companies

None.

6.c New Products Resulting from Research

The BIO-P process has been sold in a number of cities in B.C. and elsewhere (as described above). This market is still growing.

6.d Intangible Benefits

Many projects in which the department participates have application elsewhere in B.C. (and around the world).

6.e Outstanding Research Scientists Attracted to B.C.

The Pulp and Paper Chair at U.B.C. (towards which the department was a minor contributor) was awarded to Dr. Eric Hall of the Department's Wastewater Technology Centre in Burlington, Ontario.

6.f Benefits to Provincial R&D Establishments

Departmental personnel assist the Science Council of B.C. grants committees in the appraisal of relevant proposals.

7. Important Collaborative Organizations

In B.C., the division participates actively with the Science Council of B.C. and Paprican and, to a lesser extent, with MacMillan Bloedel.

Nationally, the division makes use of departmental research facilities at the National Water Research Institute in Burlington, Ontario, the National Hydrogeology Research Institute at Saskatoon, and the Technology Laboratories in Ottawa and Burlington. There are strong linkages also with Canmet on mining related issues, and co-operative efforts with several private research organizations in addition to MacMillan Bloedel.

8. Suggestions on Ways B.C. Might Derive Greater Value from the Work at This Establishment

Would like to see more direct linkages between the various federal and provincial funding agencies to simplify the brokerage of proposals. Would also like to see the Unsolicited Proposal Program re-instated.

9. Industry Overview

See the recent B.C. Science Council SPARK Environmental Sector report for background information on the industry.

10.a Recent Publications

None provided.

10.b Key Scientific or Technical Papers

Not applicable.

11. Major Projects

Not applicable.

6.4 Atmospheric Environment Services, Pacific Region

Overview

The Atmospheric Environment Service (AES) does not officially do formal research in Vancouver. Those activities take place at AES's research facility in Downsview, Ontario. However, meteorologists at the Vancouver office are active in some applied research and development activities and have enjoyed considerable success, albeit on a modest scale. Most of their R&D activity is done on time borrowed from regular weather forecasting activities. Thus it is estimated that on average about 55 weather forecasters (in various branches) devote 10% to 15% of their time to R&D. This nets out to about 7 person years devoted to such activities.

Since most of B.C.'s weather approaches from the Pacific Ocean, where weather observation posts are sparse, the group have become experts at interpretation of satellite information. This enforced interest has led to their playing a prime role in the development of some very successful data analysis tools, most notably the Metdas system, contracted to MacDonald Dettweiler and Associates, using the now defunct Unsolicited Proposal Fund. It has also led to some better techniques for forecasting marine weather, especially the dangerous rapidly developing storms, on which considerable progress has been made. The group is seeking funding to finance development of an expert system to encapsulate some of the specialist knowledge needed for correct interpretation of data in order to make good forecasts.

Overall, the group provides a nice example of what "non-scientists" can do given some tough problems, energy and intelligence, and enough leeway to get something accomplished.

1. **Address**

700 - 1200 West 73rd Avenue,
Vancouver, B.C. V6P 6H9

Contacts

Mr. Pat Pender, Director General, Pacific Region
Mr. Kirk Johnstone, Director, Atmospheric Issues and Services Branch(664-9120)
Mr. Mert Horita, Chief, Techniques, Technology and Training (664-9070)

TEL: (604) 664-9190 FAX: 664-9195

2. **Mandate/Objectives**

The Atmospheric Environment Services mandate is to provide weather, climate and air quality information for the safety of the public, the security of property, the enhancement of the environment and the improvement of the economy.

3. **Budgetary Information (in thousands of dollars)**

Year	Operating	Est. Salaries	Ext. Rev.	Capital	Total
1991/92	$380	$420			$800

Comments:

The budgetary figures are very rough only. They are calculated by assuming that the equivalent of seven person years is devoted to development activity, (shared amongst a much larger group of professional meteorologists). About $200K of the operating estimate is accounted for by a contract for development of a new meteorological work station.

4. **Person years**

Year	Research Scientists	Scientific Support	Admin.	Total
1990/91	0	7		7
1991/92	0	7		7

Comments:

The AES has its R&D facilities centralized in Downsview, Ontario. There is no formal research performed by AES in B.C., but there is some applied research and development. AES estimate that about 55 meteorologists spend 10%-15% of their time in such activities. This amounts to approximately 7 person years of R&D activity in B.C.

5.a Principal Criteria for Success

- adequate advance warning of hazardous weather conditions.
- achievement of federal environmental quality objectives.
- provision of atmospheric information required by the public and by business.

5.b Most Successful Projects

1. The development of improved techniques for forecasting rapidly developing intense storms off the West Coast. These techniques, which make better use of satellite information, have led to longer lead times for warning the marine community and the general public.
2. The remote sensing data transmission system (Metdas) developed with MDA (using the now defunct Unsolicited Proposal Fund), and which has been adopted in a number of countries.
3. Metdas was used to "animate" successive satellite views to study the effect of the jet stream on cloud boundaries and other phenomena, and hence to learn of important new mechanisms of weather development.

6.a Patents, Technical Papers and Citations

No patents. No technical papers.

6.b Spin-off Companies

None given.

6.c New Products Resulting from Research

AES has worked with MacDonald Dettweiler and Associates continuously from 1980 in the development of new weather data analysis and transmission systems which have been adopted in Canada and are now in use in several other countries including Indonesia, South Korea, Thailand and India. The group is now developing a new meteorological work station, working once again with the assistance of MDA. Although the development project is managed out of the Downsview research facility, Vancouver is the lead user for AES, and is playing a major role in the development.

Work has also been done with several B.C. companies in the development of a deep sea weather buoys. These buoys are regularly deployed in the North Pacific.

6.d Intangible Benefits

A 1985 study by the DPA Group estimated the direct economic value of short-term weather forecasts for all of Canada to be about $1.5 billion p.a. about half of which was attributed to agriculture.

6.e Outstanding Research Scientists Attracted to B.C.

No.

6.f Benefits to Provincial R&D Establishments

AES employs about 2 py's of co-op students (i.e. about 8 students p.a.), and an additional 2 to 4 summer students.

Working with the Geography Dept. at U.B.C. on issues of air quality.

Involved in the planning for the establishment of a Climate Research Facility (with Dr. Gordon McBean, U.B.C., Dr. Chris Barnes U. Vic., and MDA among others).

7. Important Collaborative Organizations

AES Research at Downsview, Ontario
U.B.C.
B.C. Forest Service (especially in lightning studies, and communication of weather forecasts to remote locations).
Greater Vancouver District
City of Victoria
B.C. Ministry of the Environment

8. Suggestions on Ways B.C. Might Derive Greater Value from the Work at This Establishment

- Help in getting the UP Fund re-instated.
- The province would be well advised to attend more of the federal-provincial meetings dealing with issues such as acid rain, smog and global warming. The Vancouver office does its best to transmit provincial messages related to these issues, but feels it would be more effective if provincial representatives attended the meetings themselves.

9. Industry Overview

This question is not applicable, but see the response to question 6d.

10.a Recent Publications

None supplied. Photocopies of extracts from the 1992-93 Estimates for Environment Canada and from a DPA 1985 report on the "Economic Value of Weather Information in Canada" are filed in the PACST library.

10.b Key Scientific or Technical Papers

None mentioned.

11. Major Projects

1. Meteorological Workstation Development

This is a four year project which is now about half completed. The project manager for the workstation development is in Toronto, but the development work is in Vancouver, and the prime contractor is MacDonald Dettweiler and Associates. An important goal of the project is to be able to combine data from a variety of sources to get a co-ordinated overview. This requires that the data be "earth registered", i.e. tied in to geographical co-ordinates.

2. Studies of Oxides of Nitrogen and Volatile Organic Compounds

These compounds have surfaced as an important environmental issue with the Canadian Council of Ministers of the Environment. The Lower Mainland is particularly prone to this form of pollution, and the AES plans to work with others in helping to predict the magnitude of the pollution at any given time, to evaluate its effects, and to devise a strategy for reducing these emissions to a more tolerable level.

3. Applied Research with Doppler Radar in Gulf Islands

It is believed that a proposed new Doppler radar facility will be useful for tracking weather systems, and assist in sewage control by giving early warning of local heavy rainstorms, thus permitting runoff water to be diverted. AES is working with provincial and municipal agencies and hopes to be able to tap into the Green Plan to find financing for this project.

4. Marine Weather Forecasting

Working with Dr. LeBlond at U.B.C., the service has already greatly improved its ability to forecast rapidly developing storms. A current problem is that the forecasting techniques require considerable experience. The service is seeking funding to develop an expert system to help surmount this problem, and thus improve forecasts in the presence of relatively inexperienced employees.

5. Smog Forecasting

This problem is complicated by some confusion over mandates. The GVRD already has an air quality monitoring network. AES plans to supplement this with more monitoring stations (in Whiterock and West Vancouver). It is believed that the new Doppler radar mentioned above will help improve the accuracy of smog forecasts.

CHAPTER 7 - FISHERIES AND OCEANS CANADA

7.1 General Overview

The Department of Fisheries and Oceans operates two major research facilities in B.C., the Pacific Biological Station (PBS) at Nanaimo (with subsidiary facilities in West Vancouver and Cultus Lake) and the Institute of Ocean Sciences (IOS) north of Victoria. These are managed by the Regional Director of Science, who reports to the Regional Director General.

The approximate budgets of the Fisheries and Oceans facilities in 1991/92 were as follows:

Facility	Est. Annual Budget($000) Internal Funds	Person Years Scientists	Person Years Total
Biological Science			
Pac. Biol. Stn.	$20,820	47	185.1
West Van. Lab.	incl. above	incl.	40
Cultus Lake Lab.	incl. above	incl.	10
TOTAL (Biol.)	**$20,820**	**47**	**235.1**
Institute of Ocean Sciences (IOS)			
Oceanography	$9,588	25	80.5
Hydrography	$5,665	11	89.2
TOTAL (IOS)	**$15,253**	**36**	**169.7**
TOTAL (Biol. + IOS)	**$36,073**	**83**	**404.8**

The *Pacific Biological Station* was founded in 1908. When combined with its West Vancouver Laboratories, it is the largest Federal research presence in B.C., with an annual budget of $20.8 million, 47 research scientists and 235 employees all told. The Institute of Ocean Sciences has a budget of $15.3 million, employs 36 research scientists and has a total complement of 170 persons, however only about 40% of the effort is devoted to research, with the remainder devoted primarily to the production of charts and to scientific data collection. Together the two organizations account for about 36% of Federal intramural R&D expenditures in B.C.

The Pacific Biological Station has devoted a large fraction of its resources over the years to the single minded pursuit of understanding the salmon and its environment, where it wanders and how it finds its way, who besides humans eats it and what it eats. In that time, it has of course tackled other

questions as well, but an understanding of the Pacific salmon has been its main endeavour, and it has enjoyed considerable success in this undertaking. The station is proud of the fact that approximately 10 percent of the annual salmon catch results from the salmonid enhancement activities resulting from their research. In more recent years, it has made important advances related to salmon farming (primarily at its West Vancouver Laboratory), and has been influential in a number of other areas including assessing the effects of pollution and of driftnet fishing, and research into the life cycle of other fish varieties, including shell fish and herring.

The *Physical and Chemical Sciences (Oceanography) Division of the Institute of Ocean Sciences* is responsible for a variety of oceanographic research projects, including studies of the influence of the oceans on climate and the greenhouse effect (where it has been at the leading edge). Institute scientists study such events as *El Nino* which brings warm water onto our coast, and affects our fish stocks. More generally, they study ocean circulation, and other physical and chemical properties of the ocean. The laboratory is deeply involved in environmental assessment issues such as toxic plankton studies, ocean dumping, site-specific pollution problems and oil spills. IOS personnel were heavily involved in the responses to the *Nestucca*, the *Exxon Valdez* and Persian Gulf oil spills, particularly in the area of predicting spilled oil movement.

The *Hydrography Division* of IOS employs some 89 people, approximately 15 of whom are involved in research. The Division produces 42% of the charts made in Canada, covering the West Coast, the Western Arctic and important inland waterways. In addition, the Division produces tide and current tables and cruising guides, and plays a major role in Canada's Tsunami warning system, with tide gauges located along the coast to indicate an approaching sea wave. The Division has been active in technology development and transfer, and has some impressive accomplishments to its credit in this sphere.

IOS activities have been pivotal to the development of the ocean industry in B.C., an industry which employed about 350 people in 1990, and had gross sales of about $25 million. The doubling time of sales in the industry is presently about 5 years.

7.2 Biological Science

OVERVIEW

The Pacific Biological Station (PBS) at Departure Bay just outside Nanaimo was founded in 1908 by the Rev. George W. Taylor who was the unpaid director of the station until his death in 1912. A very competent and energetic amateur who won admission as a Fellow of the Royal Society of Canada in 1894 for his research, he set a standard of dedication and professionalism which has served the station well. In the late 1960's, a new satellite laboratory was opened in West Vancouver which makes use of the abundance of fresh water available at the site especially for research on salmonids. There is also a small facility at Cultus Lake belonging to the station and two persons located at the Institute of Ocean Sciences near Sidney. Taken together, these groups comprise the Biological Sciences program of the Department in B.C. The Director of the Pacific Biological Station is in charge of the Biological Sciences program.

Given the vagaries of politics, and the unfortunate effects they can have on scientific research establishments, it is remarkable (and a credit to all those concerned) that for 84 years the station has been able to follow its single minded pursuit of understanding the salmon and its environment, and where it wanders. In that time, it has of course tackled other questions as well, but an understanding of the Pacific salmon has been its main endeavour, and what a challenging and complex problem it has turned out to be!

The director of the station sees it as the clear mission of the program to work towards the preservation and enhancement of the fish stock in British Columbia by providing those concerned with managing the stock with sound scientific support, and almost all research is directed to that end.

The station has access to a variety of small craft as well as the 58-metre fisheries research vessel *W.E. Ricker*, commissioned in 1986. This vessel is named after a distinguished station scientist, one of the first to develop a viable theory of fish population dynamics.

Biological Sciences staff currently comprise approximately 205 persons (excluding the 30 person crew of the research vessel), of whom 47 are research scientists. Most of the staff work out of the Nanaimo station, with approximately 40 at the West Vancouver station, 10 at Cultus Lake, and 2 at the Institute of Ocean Sciences near Sidney. The annual budget amounts to some $21 million including the cost of running the research vessel.

While the research interests of the staff cover a wide variety of marine life, there is a very strong emphasis on research related to the Pacific salmon for which the landed value in 1989 was $256 million or about 56% of the total landed value from all commercial fisheries. There was an additional $75 million in revenue from salmon aquaculture.

The salmon is also the mainstay of the sports fishing industry, which was estimated to inject $240 million into the B.C. economy in 1989. Native fisheries, although not estimated in dollar value, are also an important component of the industry.

Finally, fish processing as a whole employs some 6000 people and had wholesale revenues of just over $1 billion in B.C. in 1989.

According to Statistics Canada, the Department of Fisheries and Oceans spent about $240 million on "Science and Technology" related expenditures in 1990/91, of which almost $130 million was on R&D. 95% of these expenditures were intramural, with 4% going to industry, and 1% going to "Other Canadian". Expenditures at universities were too small to show. It would appear that DFO Science and Technology expenditures in B.C. amount to about 15% of their Canadian total. The Pacific fishery in 1990 appears to have accounted for 32% of the value of fish landings in Canada, and 29% of the processed value.

A sampling of industry statistics garnered from Statistics Canada is shown in Table 7.1 on the next page. There is a further discussion of fisheries statistics in Section 9 (Industry Statistics) below.

CANADIAN FISHERY	1990 Pacific	1990 Atlantic	1990 Inland	1990 Total
Landings (tonnes)	305,207	1,296,684	45,500	**1,647,391**
Landings ($K)	$478,192	$953,086	$78,000	**$1,509,278**
Production (tonnes)	244,100	645,960	31,000	**921,060**
Production ($K)	$951,510	$2,207,830	$130,000	**$3,289,340**
No. of fishermen	61,376	20,097	8,105	**89,578**
No. of plant workers				3,800
B.C. total licences	20,097			
B.C. active licences	15,900			
B.C. vessels	6,196			
Assoc PY: processing/packing	5,700		(PY = person years)	
Approx. total industry PY (B.C.)	21,600			
Percent of BC food mfg	25%			
B.C. Breakdown	**Landed $ million**	**Wholesale $ million**		
Salmon (excl. farm)	$261	$574		
Herring	$75	$153		
Halibut	$19	$33		
Groundfish	$61	$107		
Shellfish	$42	$68		
Total ($mill)	**$459**	**$935**		
# of Aquaculture Operations - 1990	**Number**			
Oyster	437			
Salmon	210			
Trout	88			
Hatcheries	62			
Marine plants	6			
Total	803			
Estimated value ($mill)	$85			
Source: BC E&S and from F&O direct.				

Table 7.1 - Summary Fishing Statistics, Canada and B.C. - 1990

1. **Contact**

Dr. R. J. Beamish, Director

Address

Hammond Bay Road, Nanaimo, V9R 5K6

Tel. (604) 756-7041/7040 Fax: 756-7053

2. **Mandate/Objectives**

The general mandate for science in the department is:

To ensure that the highest standard of scientific information is available to the Government of Canada for use in developing policies, regulations and legislation regarding the oceans and aquatic life, and to other government departments, private industry and the public for use in planning and carrying out aquatic activities.

Biological sciences research is defined to include both short and long term research on fish, invertebrates, marine mammals and plants, and ecosystems, which provide relevant information and advice crucial to Canadian fisheries management and development.

The Director of the laboratories defined his mission in more simple terms as the maintenance of a healthy fish stock for industry. Management are proud of the accomplishments of the station, and believe that there is no finer organization with similar aims anywhere in the world.

A listing of 17 "National Priorities" for the Biological Sciences Branch of the Department shows the first five related to fish stock assessment, and the next five related to aquaculture. The remaining seven relate to toxic chemicals, marine environmental studies, and an examination of the impact of the greenhouse effect on fisheries, and of the role of oceans in the CO_2 cycle.

3. **Budgetary Information (in thousands of dollars)**

Year	Operating	Est. Salaries	Contracts	Capital	Total
1988/89	$7,348.5	$14,094.0	$4,747.0	$1,078.2	$22,520.7
1989/90	$7,488.6	$14,154.0	not available	$669.9	$22,312.5
1990/91	$8,848.5	$14,358.0	$2,699.1	$799.5	$24,006.0
1991/92	$6,212.4	$14,106.0	$1,754.3	$501.1	$20,819.5

Comments

1. Contract expenditures are included in operating costs data. Expenditures for the year 1988/89 break down roughly as follows: $2.7 million for scientific data collection

(primarily stock assessment), $1.928 million with Canadian industry, $92,000 with Canadian universities, and $22,000 "foreign" and "other".

2. The cost of ship time is included in these numbers. The cost of ship time has varied somewhat over the years. Starting in 1988/89 and running to 1991/92, the annual operating costs of ship time were as follows: $738.6, $831.7, $1116.5 and $984.3.

3. The TOTAL expenditures are arrived at by adding operating and capital expenditures to the salary cost. This latter number is derived by multiplying the number of person years shown in the table below by $60,000. Clearly this latter number is approximate and has undergone some inflation over the time period, but no adjustments for salary inflation have been made in the figures shown.

4. **Person Years**

Year	Research Scientists	Scientific Support	Admin.	Total
1988/89	50	158.3	26.6	234.9
1989/90	51	158.8	26.1	235.9
1990/91	50	162.0	27.3	239.3
1991/92	47	158.9	29.2	235.1

Comments:

1. These data include the person years required to maintain and run the ships. These amount to 27.7 py's in 1988/89, rising to 34.6 in 1991/92. The scientific establishment excluding those associated with the ships has been fairly stable at just over 200 py's over the period. In fact, the base person years have declined, but the deficit has been made up by special programs such as the Green Plan and native programs.

2. Approximately 15% of the staff work out of the West Vancouver Station, 7% out of Cultus Lake, 2% out of IOS, and the remainder out of Nanaimo.

5.a **What are your principal criteria for success?**

The station believes that a major index of its success is the health of the fish stock in B.C., and the health of the fishing industry more generally.

Individual scientists are measured by standard academic criteria related to the number and quality of publications as well as by their contribution to the objectives of the research program. (There are an average of three primary publications per research scientist per year.)

The station is reviewed annually internally and selectively by an external (scientific) review committee. In addition, the Pacific Stock Assessment Review Committee monitors the fish stock.

The Director also believes that the fishermen are strongly supportive of the station's work. He clearly believes this to be important.

5.b What have been or are your most successful projects according to these criteria?

The director indicated that there are over 200 projects under way, about 80% of which are directed at the salmon fishery. The research scientists at the station are divided into four divisions: marine fish, aquaculture, salmon and habitat. He did not wish to pick key projects.

We have selected the following notable successes for mention:

1. Salmonid enhancement efforts led by the station have enhanced salmon stocks to the point that it is estimated that 10% to 15% of salmon caught commercially originated from the program.

2. Research led by Dr. Ed Donaldson at the West Vancouver Laboratories which resulted in techniques to ensure that all Chinook salmon for use in aquaculture are female (females are larger and all mature at the same time).

3. It has been determined that electrophoresis can be used to determine the river (and in some cases, the stream and spawning bed) of origin of pink and chum salmon caught in the open seas with great accuracy.

4. Research aimed at controlling various salmon diseases (notably BKD(bacterial kidney disease)) which infect cultured salmon.

5. Investigations into the effects on fish stocks of drift net fishing in the North Pacific. These studies date from the early days of drift net fishing. An important early achievement was the development of ways to identify North American salmon caught by the driftnetters on the high seas (by the detection of some fresh water fish parasites). With this knowledge, it was possible to establish measures to protect the stock from depletion on the high seas via international conventions.

6.a Patents, Technical Papers and Citations

A list of technical papers is included in the *Pacific Region Science Review*. The 1988/89 and 1989/90 copies of this document are on file in the PACST library.

Patents on techniques for the use of DNA identification of female Chinook salmon and release capsules for growth hormones are pending. Other patents were issued in 1991.

6.b Spin-off Companies

There are no spin-offs of which we are aware apart from the fact that some staff have become independent consultants.

6.c New Products Resulting from Research

The Microtek Micrologics Company in Victoria has a license to use genetic probes to determine the sex of monosex Chinook salmon for the aquaculture industry. In 1991 its sales of sampling salmonids were approximately $25K, and it employed 1-2 people.

Island Scallops is a privately owned company which received assistance from the Pacific Biological Station in the area of disease diagnostics and nutrition. This company also received financial assistance from both federal and provincial sources.

6.d Intangible Benefits

The station has had a major impact on awareness of man-induced factors affecting the fish stocks, including pollution, landslides and spawning bed alterations from logging practices. The work conducted here was fundamental to the development of codes of practices in a number of industries.

6.e Outstanding Research Scientists Attracted to B.C.

No response.

6.f Benefits to Provincial R&D Establishments

The station regularly employs co-op students from the co-op programs at UVic and SFU (UBC has no co-op programs in fish biology).

There is some co-operative research with the universities, but not as much as there might be. There is often not a good match between the tight time schedules of the station's research program and academic research, much of which perforce takes place in the summer. There are a number of graduate students who carry out research in co-operation with the station.

7. Important Collaborative Organizations

The Station has a number of joint programs with the Japanese research community, including DNA stock identification, high sea production modelling, marine fish culture and biotechnology.

Particular admiration was expressed for the work of the Russian research establishments which accomplish a lot in difficult working conditions and on a low budget.

8. Suggestions on Ways B.C. Might Derive Greater Value from the Work at This Establishment

No particular suggestions, with the possible exception of a small cry for support in the face of budgetary squeeze being experienced almost everywhere in government. The following extract from the *DFO Pacific Science Workplans for 1991-92* (pp.3-4) is instructive concerning the demands placed on the station.

"While in most instances [fish] stocks are healthy in the Region and indeed record salmon returns have been recorded coastwide, there are problems in some areas. Specific resource concerns include the seriously depressed condition of Chinook salmon stocks in the Strait of Georgia, a similar emerging problem with coho stocks in the area, the need to close ling cod fisheries in the Strait and concerns about rockfish stocks in that area. In addition, it has been necessary to close the abalone fishery coastwide due

to depleted stock status. Overall, there is concern with respect to a number of specific 'minor' stocks and a need to develop new management regimes for them and engage in specific stock rebuilding activities. There is also concern about the rapid increase in abundance of seals in coastal waters and the impacts of seals and sea lions on salmon and other species. Public interest in marine mammals, particularly killer whales, is creating demands for expanded program activity in this area as well.

"Major scientific responsibilities enfold the concern for contaminants problems in the region, particularly as a result of the nature of the salmonid life cycle and the impact of industry and development on freshwater, estuarine and coastal environments and their resource base. Application of high resolution analytical chemistry to analysis of shellfish and other species in the vicinity of coastal pulp mills has lead to extensive closure of fisheries in a number of areas and strong public demands for action. Construction of a major new dioxin analytical facility [has just been] completed at the Institute of Ocean Sciences... [T]he new lab will contribute significantly to the study of such problems. Concerns about spills of oil and other hazardous chemicals in the marine environment and the need to follow up on the findings of a recent federal public enquiry will pose a challenge to the program along with a possible requirement to defend and recover Canada's expenditures in a legal case related to a recent oil spill. Expertise from our programs is also being fed into Canada's effort in the Arabian Gulf war in relation to the massive oil spill in the area.

"Science programs in the Region are increasingly being subjected to challenge and question, particularly as allocation conflicts between resource users intensify and more people compete for a finite resource base. Land claims settlement and Native policy promise to have a major impact on science activities, particularly if Native groups develop their own stock assessment and biological science capacity as has occurred in the United States.

"The above demands, and those mentioned in more detail in program work plans, coupled with limited availability of resources has necessitated extensive prioritization of programs and created many gaps that cannot be resourced. It is not possible to address all demands and it is becoming increasingly difficult to deliver core activities. There is a growing dependence on non-A-base resources and a great concern about delivery of quality science in the face of many conflicting demands. Management focus is increasingly on delivering a strong science program with quality results in a limited number of areas and within resource constraints."

9. Industry Overview

Summary industry statistics are shown in Table 9.1.

In 1989 the commercial fisheries catch was 294,000 tonnes, of which 89,000 tonnes were salmon, 41,000 tonnes were herring, 21,000 tonnes were shellfish, 4,600 tonnes were halibut, and 129,000 tonnes were groundfish, and 1,000 tonnes were other species. The landed value of the catch was $454 million, of which $256 million was for salmon, $76 million for herring, $55 million for groundfish, $46 million for shellfish, $19 million for halibut, and $2 million for other species. A total of 20,578 fishermen were eligible to fish commercially.

Some idea of the variability of the fish catches can be obtained from the following summary of salmon landings in B.C. (catches and values are approximate):

Year	Catch in Tonnes	Value
1961	55,000	$30 million
1966	75,000	$40 million
1971	62,500	$40 million
1976	55,000	[1]$80 million
1981	75,000	$160 million
1986	100,000	$260 million
1989	89,000	$256 million

By the end of 1989, there were 222 salmon farms approved for operation in B.C. Salmon production was 12,385 tonnes with a reported farmgate value of $75 million, or about 23% of total salmon value from B.C. for the year. In addition, shellfish tenures (mostly oysters) yielded about $3 million in sales, and rainbow trout farms produced a further half million in revenues.

The fish processing and marketing industry employs some 6,000 people in B.C., and had sales in 1989 of $1.02 billion, 66% of which were export sales, with salmon accounting for 68% of export value. Herring roe shipped to Japan accounted for a further 16% of total value.

Sports fishermen spend in excess of $240 million annually in B.C. on activities related to sports fishing, including accommodation, food, travel, bait and licences. A further estimated $300 million was "invested" in major durables such as boats and property. 370,000 tidal sports fishing licenses were issued to adults in 1989, of which 67% went to B.C. residents, 7% to other Canadian residents, and 26% to foreign tourists. It is estimated that about 1.4 million salmon were caught. Tonnage statistics are not available, but if the average fish were three pounds, this would amount to approximately 2000 tons.

The Indian food fishery annual salmon catch was estimated at just under 1200 tonnes in 1989. This is an increase of about threefold since 1970.

10.a Recent Publications

The following publications have been provided by the station and are filed in the PACST library:

1. *Fisheries and Oceans Pacific Region 1990 Fact Sheet* - A succinct and useful 8-page summary of fishery statistics (which formed the basis for the information supplied in question 9 above.

2. *DFO Factbook* - A 67-page summary of facts concerning the Department of Fisheries and Oceans. Published in 1989, it outlines departmental "organization, responsibilities, activities, resources, clients, history, and other relevant facts."

3. *DFO Pacific Science Work plans, 1991/92* - A 282-page internal working document setting out detailed project plans for both the Pacific Biological Station and the Institute

[1]Note that in 1975 the catch was only 35,000 tonnes and revenues were $40 million!

of Ocean Sciences. It has served as the basis for much of the summary data in this document, particularly the responses to question 11 below.

4. *Legacy of a Gentleman* - A 22-minute video tape made in 1991 by Telesis Communications (under contract from the station), which describes the founding of the station, and provides insights into the current research programs.

Other relevant documents are listed under the response from the Institute of Ocean Sciences.

10.b Key scientific or technical papers published by researchers at your laboratory over the past five years:

A list of technical papers is included in the *Pacific Region Science Review*. The 1988/89 and 1989/90 copies of this document are on file in the PACST library.

11. Major Projects

The Pacific Biological Station has approximately 200 projects underway. In the discussion below, they have been grouped into three major programs. This data is drawn from the DFO Pacific Science Work plans, 1991/92.

1. Resource Assessment and Related Research

Focus: Continue providing stock assessment and population dynamics in direct support of management and international negotiations. Improve fishery-based data quality in salmon and groundfish. Implement a ground fish observer program. Improve access and efficiency of salmon stock assessment database. Continue support for Regional Salmon task forces and increase involvement of science initiatives in stock rebuilding with new emphasis on abalone, ling cod and rockfish. Provide support to Canada-US Treaty, Lower Georgia Strait rebuilding, seine bycatch investigations, salmon stock identification, coho salmon productivity, climate change studies, factors affecting survival and recruitment, coho salmon productivity.

Program Size, Cost: The program employs some 118 person years and involves the expenditure of about $3.1 million in operating budget (excluding salaries), and about $230 K in capital.

Major achievements include the development of fishery assessment indices, and the modelling of these indices with other biotic and abiotic factors which determine the productivity of the stock in question.

These types of models are key to understanding fluctuations in fish stocks for the purpose of fisheries management, and are regularly used in regional as well as international negotiations on salmon, hake, halibut, and other species.

2. Habitat Research

Focus: Continue to provide advice and research in support of habitat management initiatives, particularly quantification of habitat loss or gain, support for the Fraser River Green Plan, Environmental Assessment Review Panel, specific habitat concerns, with a focus on sockeye and pink habitats, the Fraser estuary and on contaminants.

Program Size, Cost: The program employs some 25 person years and involves the expenditure of about $575 K in operating budget (excluding salaries), and about $28 K in capital.

Major achievements include the successful development of several industry practices, and especially the B.C. Coast Logging guidelines.

The work is conducted in conjunction with the provincial government and with private industries responsible for such activities as logging, pulp and paper, mining, hydro, and ocean dumping.

3. Aquaculture and Enhancement Research

Focus: Continue salmon aquaculture programs, biotechnology and genetics, increase emphasis on marine species and depressed stocks. Increase emphasis on environmental stress, toxic algal blooms, sea lice.

Program Size, Cost: The program employs some 41 person years and involves the expenditure of about $830 K in operating budget (excluding salaries), and about $210 K in capital.

Scientists on this program work with the fisheries enhancement and aquaculture industry to develop methods for successful rearing, breeding and nutrition of salmon and other marine fish and shellfish. In addition, this group identifies major fish disease problems and develops therapeutic methods for their control.

The work of this group is necessary for a successful Salmonid Enhancement Program, and a profitable aquaculture industry. It provides information bases for ensuring that the aquaculture and wild fish biological interactions are kept positive. The primary research links are with the universities, the Salmonid Enhancement Program and with the aquaculture industry. There are also a number of national and international working groups on which the research group is represented as part of a team approach to answering specific common problems with respect to such items as parasites, disease, and toxic algae.

4.3 The Institute Of Ocean Sciences

OVERVIEW

The Institute of Ocean Sciences (IOS) at Patricia Bay, 30 km from Victoria was opened in 1979. It shares its site with the Pacific Geosciences Centre, operated by the Department of Energy, Mines and Resources and a scientist from the Canadian Wildlife Service of the Department of the Environment.

Institute programs focus on understanding the oceans, particularly those of the North Pacific and Western Arctic. There are two major divisions of activity at IOS, Physical and Chemical Sciences (Oceanography) and Hydrography.

The Physical and Chemical Sciences Division comprises just under 80 people, most of whom are involved in scientific activities. It is responsible for a variety of oceanographic research projects, including studies of the influence of the oceans on climate and the greenhouse effect. Institute scientists study such events as *El Nino* which brings warm water onto our coast, and affects our fish stocks. More generally, they study ocean circulation, and other physical and chemical properties of the ocean. The laboratory is deeply involved in environmental assessment issues such as toxic plankton studies, ocean dumping, site-specific pollution problems and oil spills. IOS personnel were heavily involved in the responses to the *Nestucca* and the *Exxon Valdez* and Persian Gulf oil spills, particularly in the area of predicting spilled oil movement. Recently, institute scientists provided the first observational evidence to support theoretical predictions concerning the absorption of greenhouse effect gases by the ocean.

The Hydrography Division employs some 89 people, approximately 15 of whom are involved in research. The Division produces 42% of the charts made in Canada, covering the West Coast, the Western Arctic and important inland waterways. In addition, the Division produces tide and current tables and cruising guides, and plays a major role in Canada's Tsunami warning system, with tide gauges located along the coast to indicate an approaching sea wave.

The IOS site serves as the base for all DFO vessels operating on the coast, both fisheries enforcement patrol craft and science and hydrographic vessels. Just under one hundred persons are involved with manning and maintaining this fleet of six major vessels, two of which are used for fisheries patrol, three for oceanography/hydrography, and one for fisheries research.

One of the oceanography/hydrography vessels is heavily used for university-based research activities.

Overall, the activities of the Institute are a mix of research (about 40%) and other science related activities (about 60%). The facility stands out as having made a serious, sustained, and successful effort both to transfer lab-developed technology to industry as well as to work with industry to develop new technology. However budget cutbacks combined with the demise of the DSS Unsolicited Proposal Program appear to have seriously eroded this effort over the past five years.

1. **Contact**

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2. **Mandate/Objectives**

The general mandate for science in the department is:

To ensure that the highest standard of scientific information is available to the Government of Canada for use in developing policies, regulations and legislation regarding the oceans and aquatic life, and to other government departments, private industry and the public for use in planning and carrying out aquatic activities.

The Physical and Chemical Sciences Division mandate encompasses the study of the ocean's physical properties, processes and phenomena; behavior of organic and inorganic materials and their impact on fish and ecosystems; and pollutants. Instruments for carrying out these studies are developed and frequently transferred to the ocean industry.

The Canadian Hydrographic Service conducts bathymetric, tide and current surveys, and prepares and distributes navigational charts, tide and current tables, sailing directions and related publications. Research undertaken in the division is directly related to improvements of the service provided.

3. **Budgetary Information (in thousands of dollars)**

Year	Operating	Est. Salaries	Contracts	Capital	Total
1988/89					
Oceanography	$2,968.0	$3,300.0	$2,988.4	$1,072.7	$7,340.7
Hydrography	$1,414.5	$3,418.5	$527.0	$176.0	$5,009.0
1989/90					
Oceanography	$3,443.2	$3,485.0	$1,341.7		$6,928.2
Hydrography	$1,882.5	$3,627.0		$250.0	$5,759.5
1990/91					
Oceanography	$4,252.2	$3,936.5		$2,101.1	$10,289.8
Hydrography	$1,761.5	$4,019.4		$343.0	$6,123.9
1991/92					
Oceanography	$4,621.0	$4,247.6		$719.0	$9,587.6
Hydrography	$1,391.1	$4,108.6		$165.0	$5,664.7

Comments:

1. "Oceanography" refers to the Physical and Chemical Sciences Division.

2. Operating expenses do not include salaries.

3. Contract expenditures are available for 1988/89 only. About $2.2 million of the total was used for R&D contracts with industry.

4. The figures quoted exclude the cost of administration ($736 K in 1991/92), and the cost of running the ships (about $2 million operating plus $4.1 million in salaries in 1991/92. The operating budget was down from $2.8 million in 1988/89).

5. The TOTAL expenditures are arrived at by adding operating and capital expenditures to the salary cost. This latter number is derived by multiplying the number of person years shown in the table below by an average annual salary number which varies between $38,410 and $52,765 depending on the year and the division.

4. **Person Years**

Oceanography Division (Physical and Chemical Sciences)

Year	Research Scientists	Scientific Support	Admin.	Total
1988/89	25	29	21	75
1989/90				78
1990/91				79
1991/92				80.5

Hydrography Division

Year	Research Scientists	Scientific Support	Admin.	Total
1988/89	11.0	96.9	12.0	89
1989/90				93
1990/91				92.4
1991/92				89.2

Comments:

1. Scientific Support does not include the personnel who operate the research vessels. In 1988/89, those responsible for operating the ships came to 38.4 py's for Oceanography, and 22.8 py's for Hydrography.

2. Detailed breakdowns of person years were available only for 1988/89.

3. As already stated, the person year figures given above exclude those devoted to the running of the vessels (107.6 py's in 1988/89 declining to 97.5 py's in 1991/92). They also exclude Administration and Support (25 py's in 1988/89 declining to 24.6 py's in 1991/92).

5.a Principal Criteria for Success

The principal criteria for success were listed as:

- Scientific productivity and generation of new knowledge relevant to the problems of today and tomorrow.
- Scientific excellence (peer recognition).
- Understanding of the oceans which assists with proper stewardship of those oceans.
- Scientific support to major clients (e.g. marine transportation, pollution and oil spill response, fishing, aquaculture)

5.b Most Successful Projects

There are close to 50 program areas in IOS. It is difficult to single out particular projects. The Institute is particularly recognised internationally for its research in ocean turbulence, ocean modelling, descriptive and analytic coastal oceanography, and the ocean's role in greenhouse gas uptake.

The Hydrography Division produces about 42% of the charts sold in Canada.

6.a Patents, Technical Papers and Citations

A listing of technical papers published during the year is contained in the annual edition of the *Pacific Region Science Review*. The most recent copy (1989-90) lists 37 primary publications (pp. 73-76).

6.b Spin-off Companies

The **Axys Group** (formerly the **Seakem Group**) of companies has been the most successful spin-off company from the Institute. It was started in 1974 by three U.B.C. graduate students, two of whom were working at DFO. The group now employs over 110 persons and has sales of over $10 million. Based in Sidney, B.C., it has offices in Vancouver and Dartmouth, Nova Scotia. The company, which got its start in oceanographic consulting, has now branched into optical fibre products, high purity chemical production, marine instrumentation, analytical services (currently about 40% of its business), and the sale of software.

Arctic Sciences of Sidney, B.C. was also formed by ex-employees (in the 1975 time frame), and now comprises some 10-15 people with consulting expertise in Arctic Physics. The company has also just commenced manufacturing a promising acoustic current flow meter under license from the joint patent holders, who include IOS.

Another spin-off company, **Interac Computing**, did not survive, but spawned about eight other companies, one of which is **Questar Tangent**, which now has sales of about $1 million p.a. This company produces integrated systems for automated hydrography which were first developed for IOS and which are currently sold in Singapore, Australia and Japan.

6.c New Products Resulting from Research

The Sidney, B.C. office of **Terra Surveys** of Ottawa, Ontario has adopted and adapted an airborne laser hydrographic surveying device called LIDAR developed by Optek in Ontario. Terra's first contracts for surveys using this device were with the Hydrographic Surveys Group at IOS. IOS continues to contract with Terra, who have since obtained contracts with Indonesia, Ontario Hydro, and the U.S. National Oceans and Atmosphere Administration (NOAA). Total contracts over the past five years have amounted to about $3 million, but the company believes that within a few years annual revenues could reach $7-$10 million, most of it coming from outside Canada. IOS was described as "extremely good to work with", and as providing crucial help and support during the learning phase of the process, so that Terra can now bid on overseas contracts with confidence.

Although the primary contact for **International Submarine Engineering Research Ltd.** (ISER) for a series of contracts to develop a "Deep Ocean Logging Platform with Hydrographic Instrumentation and Navigation" (DOLPHIN) was with a sister institute of IOS in Bedford, Nova Scotia, it is nonetheless important to mention this major (well over $3 million) development which originated with an Unsolicited Proposal Fund contract in 1981. DOLPHIN can potentially substantially increase the efficiency of hydrographic surveys by running a number of these very stable instrumentation platforms in parallel from one manned vessel. U.S. Navy interest in the DOLPHIN has been high, and has resulted in a number of follow on contracts, but major sales have yet to come about.

IOS has also played a major role in the development of **Applied Microsystems Ltd** of Sidney, which employs about 15 persons in the manufacture of instrumentation.

IOS worked very closely with the software division of the Axys Group in the development of *Quickmap*, a geographic information system which is being marketed world wide.

6.d Intangible Benefits

Most of IOS's intangible benefits to B.C. have been in the domain of environmental improvements as a result of a better understanding of the oceanographic processes governing the dispersion of such human actions as oil spills and industrial water pollution, as well as in the contribution of knowledge about ocean circulation, salinity and temperature to models of fish migration and survival.

6.e Outstanding Research Scientists Attracted to B.C.

IOS has attracted several scientists with important international reputations. Most IOS scientists are Canadian. At any given time, there will be about three to six visiting scientists at the Institute from all parts of the world.

6.f Benefits to Provincial R&D Establishments

The Institute works closely with B.C. universities, especially UVic and U.B.C. where several scientists hold adjunct professorships. One of IOS's research vessels is heavily devoted to support of university research projects. There are routinely a PhD program, and whose thesis and work supervision comes from IOS. Approximately 15 summer students are employed in an average summer. IOS is also a sponsor of the Shad Valley Program. IOS staff serve on some Science Council of B.C. committees.

7. Important Collaborative Organizations

The most important organizations with which we collaborate are U.B.C. (Oceanography), the Pacific Biological Research Station in Nanaimo, U.Vic., and Royal Roads.

8. Suggestions on Ways B.C. Might Derive Greater Value from the Work at This Establishment

The effectiveness of our work with industry was greatly curtailed by the demise of the (federal) Unsolicited Proposal Program. Almost all the companies listed in the answer to questions 5b and 5c were financed in substantial measure through our involvement with that fund. If the provincial government can do anything either to persuade the federal government to re-instate it, or to initiate one of its own, that could be very helpful and effective for the province.

9. Industry Overview

The Oceanographic Research supports the fishing industry, though not as directly as does the Pacific Biological Station. However, an understanding of the way in which ocean conditions affect fish stocks is an important result of IOS oceanographic research. Information on water temperature and circulation is also important to the

aquaculture industry. Charts and tide tables support all shipping on the coast, including recreational craft. In the long term, the pollution research carried on by the Institute is supportive of the government's regulation of the shipping, pulp and paper and mining industries.

10.a Recent Publications

The following materials are available in the PACST library except where indicated. Some deal with both the Institute of Ocean Sciences and the Pacific Biological Station (including its West Vancouver offices), so that the relevant publication may be found under PBS rather than IOS.

1. *DFO Factbook* - A 67 page summary of facts concerning the Department of Fisheries and Oceans. Published in 1989 it outlines departmental "organization, responsibilities, activities, resources, clients, history, and other relevant facts."

2. *DFO Pacific Science Work plans, 1991/92* - A 282 page internal working document setting out detailed project plans for both the Pacific Biological Station and the Institute of Ocean Sciences. It has served as the basis for much of the summary data in this document, particularly the responses to question 11 below.

3. *Unravelling the Mysteries* - A 17 minute video tape made in 1990 by Gastown Post and Transfer Ltd. under contract from the IOS. It describes a number of activities of the IOS. (Not available in the PACST Library)

4. *Pacific Region Science Review* - An annual review of the Department of Fisheries and Oceans scientific activities which covers both IOS as well as the Biological Sciences Branch. The reports are 100 to 150 pages in length and are essential reading for anyone wishing a more detailed overview of the department's research programs in B.C. The PACST library has reports for the years 1988/89 and 1989/90.

5. *Report on the Ocean Science and Technology Sector of the Oceans Industry of British Columbia* (Economic and Commercial Analysis Report No. 25, DFO, July, 1989) - A 34 page report on the ocean science industry in B.C. which highlights the important role played by federal government contracts in the development of the industry.

6. *Cases of Technology Transfer* and *Economic and Technological Benefits* - These two reports were both produced by the Economic and Commercial Analysis Directorate of the Department of Fisheries and Oceans in 1988. They cover activities on both the Atlantic and the Pacific coast, and provide useful information on the extent of the industrial research support activities not only of the department, but also of other government departments, provincial governments and the private sector. Both reports are under 50 pages in length.

7. *Evaluation of Technology Transfer from Ocean Science and Surveys Ships at the Institute of Ocean Sciences, Patricia Bay, B.C.* - A 52 page consultant report (by Marvin Shaffer and Associates Ltd.) commissioned by DFO in 1985. Although a little out of date now, it provides useful information on specific developments and the companies involved.

10.b Key Scientific or Technical Papers

See response to question 6a above.

11. Major Projects

Some of the major oceanographic projects are:

1. Continental Shelf and Margin Studies

About 14 person years are devoted to a variety of small projects, including an examination of oceanic influences on fish recruitment, models for interpolating and projecting from data and climatological observations from B.C. coastal stations, processing of oceanographic data from the Beaufort Sea Ice Motion Project and field studies of ice deformation. The coastal oceanography of B.C. is now reasonably well defined.

2. Large Scale Ocean Circulation and Climate Studies

About 13 person years are devoted to a variety of observational programs, collaborative work at the Cobb Seamount and the Juan de Fuca ridge, international data exchanges (Japan, Russia), and a variety of modelling activities. The work includes examination of the large scale transport of heat, and is tied into modelling the impacts of climate change.

3. Contaminant Chemistry Studies

13 person years are devoted to such projects as dioxin analysis (in the new facility), ecosystem modelling of oil biodegradation, analysis for metal binding proteins in the livers of coho, Chinook and crabs, and the development of new tests and analytical methods. IOS plays a crucial role in understanding the fate and effects of contaminants in the marine environment.

4. Climate Chemistry Studies

7 person years are devoted to research and data collection aimed at obtaining a better understanding of the processes by which CO_2 from the atmosphere is taken up in the ocean. This work is at the leading edge internationally, and has provided the first observational evidence to support theoretical predictions of the significance of the ocean's role in the greenhouse effect.

Research in the *Hydrography* section includes the following:

1. Various Studies

Almost 7 person years are devoted to crustal movement studies, examinations of surface currents in Northern B.C. waters in support of spill prediction and in narrow passes and multibeam echo sounder trials. B.C. has some of the strongest tidal currents in the world.

2. Arctic Hydrography Studies

About 3 person years are devoted to work in hydrographic acoustics in the arctic, including work with a correlation sounder. Also included is systems and software work to increase the use of computers in the field.

CHAPTER 8 - FORESTRY CANADA

8.1 Overview

Forestry Canada started life about 90 years ago as the Dominion Forest Service, a branch of the Department of the Interior. Since that time the Forestry Service has had its home in a number of departments, including Mines and Resources (1936-1950), Northern Affairs and National Resources (1953-1969), Dept. of Forestry (1960-1966), Fisheries and Forestry (1969-1971), Environment (1971-1978 and 1980-1984), Agriculture (1984-1988) and finally Forestry again in 1988!

The Pacific Forestry Centre (PFC) was established at its present site in 1965, having moved from quarters in downtown Victoria where the Dominion Forest Pathological Laboratory had been established in 1940. The first priority of the Pathology Lab in 1940 was to investigate decay in the Sitka spruce being logged in the Queen Charlotte Islands for the manufacture of aircraft for use in the war. Historically, the focus of the centre has been on reducing the depredations of our forests from "bugs and fire", but this role has broadened in recent years. In very general terms, wood losses from disease and fire come to 10% and 5% respectively of the cut in B.C. in an average year.

"Conducting and fostering research and development in the forest sector" is one of the three principal pillars on which the Forestry Canada mandate stands, and the Pacific Forestry Centre (and its small satellite centre at Prince George) is one of six such regional facilities located across Canada. In addition, Forestry Canada operates two national research facilities, the Petawawa National Forestry Institute at Chalk River, Ontario, and the Forest Pest Management Institute in Sault Ste. Marie.

An important part of the role of the PFC is in the delivery of biological science to forest resource owners and users. Technology transfer is combined with a normal research role where Centre scientists endeavour to participate in solving current biological problems with important economic implications. About 48% of the budget and about 19% of the manpower at the centre is involved with industry, trade and development, while the remaining 52% of the budget and 81% of the manpower are devoted to research, including technical and administrative support of research, and the delivery of science.

The budget of the Pacific Forestry Centre for 1991/92 was as follows:

Facility	Est. Annual Budget($000) Internal Funds	Person Years Scientists	Person Years Total
Research	$14,120.0	47	148
IT&D[2]	$13,236.8	0	34
TOTAL	**$27,356.8**	**47**	**182**

Included in these figures is $11.2 million of Federal contribution to the Canada-British Columbia Partnership Agreement on Forest Resource Development (FRDA II). FRDA II is a $200 million, five year cost sharing program, $11.6 million of which is spent on research at the Centre in forest protection, advanced forest technologies, integrated resource management, stand tending and forest renewal. About $76 million of the Federal contribution goes towards tree planting and improving the value, quality and health of young stands through stand tending. Of the $11.2 million spent under the FRDA agreement by the Centre in 1991/92, $1.3 million was for research.

The region maintains a District Office at Prince George with a staff of five persons including a research manager (at the same site as the Agriculture Canada Prince George Research Station). The Prince George group are involved in research and technology transfer projects developed through discussion with local clients.

Some of the key research projects undertaken by the Pacific Forestry Centre include:

- the successful development of methods to control the export of the Pinewood Nematode in lumber scheduled for export to Europe.

- research in the remote sensing of soil compaction to help quantify environmental impacts. Licensing/patenting of this development is in process.

- forest ecosystem dynamics research, aimed at understanding how ecological processes and biodiversity may be affected by changes in the forest and atmospheric environments.

- survey of forest insect and disease conditions in B.C. and the Yukon.

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[2]Industry, Trade and Development, an economic analysis and business issues activity.

- functional pest management systems development for Douglas-fir beetle, Douglas-fir tussock moth, Douglas-fir seed orchard pests, nursery diseases and dwarf mistletoes.

- population model development for the mountain pine beetle. The model is being used for forest management purposes, and similar models for understanding the impacts of a variety of other pests including laminated root rot, spruce weevil and budworms are being developed.

- the Canadian Forest Fire Danger Rating System which is now used operationally in many countries of the world was developed (in co-operation with other Forest Canada facilities).

- alternative silviculture and wood harvesting systems are being researched and tested.

Forestry Canada also provides international seed testing and certification, nursery pest diagnosis, genetic finger printing for gypsy moth, watershed hydrology modelling and biocontrol of weeds as services to industry.

A major new initiative is research into the forest resource management implications of remote sensing, combined with a program to develop the appropriate technology for forestry applications.

8.2 A Statistical Overview

No one in B.C. needs convincing of the importance of the forest industry to the province. Some key indicators are:

* British Columbia has 603,000 square km of inventoried forest land (15% of the Canadian total), containing 8,867 million cubic metres of wood (38% of the Canadian total, and 46% of the Canadian softwood total). Over 95% of productive forest land in B.C. is crown land.

* B.C. value added from the principal forest industry activities (with B.C.'s share of the Canadian total in brackets) in 1987 was: logging - $1.454 billion (53%); pulp and paper - $2.542 billion (23%), and sawmills and other - $3.089 billion (47%). The total value added from all these activities in 1987 was $7.085 billion, or about 35% of total Canadian value added.[3]

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[3]Source: Canada Year Book, Statistics Canada, 1992

* It is estimated that in Canada there is an average loss of 110 million cubic metres of wood per year due to insects (65 million m^3) and diseases (45 million m^3). B.C.'s annual loss from insects and disease is 10.2 million m^3 or about 12% of the annual harvest (in 1987/88). Fire destroys (on average) another 4.8 million m^3 in B.C. annually.

* The Forestry Canada budget in 1988/89 was $256 million (1,283 person years), of which $67.8 million (26%) was spent on Research and Development, and a further $7.6 million on related scientific expenditures. 84% of science funding was spent intramurally, 11% with industry, 2% at universities and 3% with other Canadian sources.[4] R&D expenditures in the period 1987-1991 have been roughly constant ($2 million), i.e. they have declined in constant dollars at about the inflation rate. Including FRDA contributions, Forestry Canada spent $49.9 million in B.C. in 1988-89, or roughly 20% of its total budget.

* It is interesting to note that Forestry Canada spends about 20% of its R&D budget in B.C. This is a relatively small percentage compared to the 35% B.C. share of total Canadian value added from the forest products industry, and its 53% share of Canadian logging revenues.

8.3 The Pacific Forestry Centre

1. Contact

Dr. T. John Drew, Director General
Mr. Kerry C. Deschamps, Technology Transfer Forester

Address

506 West Burnside Road, Victoria, V8Z 1M5

tel. (604) 363-0600 FAX:363-0775

2. Mandate/Objectives

Forestry Canada's mission is "*To promote the sustainable development and competitiveness of Canada's forest sector for the well-being of present and future generations of Canadians.*"

The Pacific and Yukon Regional program "is developed around two broad themes of (1) Research and (2) Industry, Trade and Development."

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[4]Sources: *Forestry Canada Annual Report, 1988/89* and *Federal Scientific Expenditures - 1990-91*, Statistics Canada 88-204, p. 29

The 1991-1995 Strategic Plan for the region lists impacts of forest use, sustaining forest productivity, integrated pest management, and fire management as key components of its science program.

3. **Budgetary information (in thousands of dollars)**

Year	Operating	Est. Salaries	FRDA Contrib.	Capital	Total
1988/89	$6,682.2	$2,193.1	$3,742.8	$913.4	$13,531.5
1989/90	$2,361.7	$7,566.7	$3,802.7	$823.0	$14,554.1
1990/91	R&D figures not available (re-organization in progress)				
1991/92	$3,008.1	$8,729.1	$1,296.0	$1,086.8	$14,120.0

Comments (including source of funds)

1. FRDA Contribution refers to the contribution to R&D arising from the Federal-Provincial Forest Resource Development Agreement which runs out (unless renewed) in 1995.
2. Dollar amounts shown include the cost of administration attributable to the R&D operations.
3. In 1991/92, expenditures on R&D at the Prince George Satellite Station were $52.7K in Operating expenses, and $86.6K in salaries.

4. **Person years**

Year	Research Scientists	Scientific Support	Admin.	Total
1988/89	52	71	22	146
1989/90	52	71	22	146
1990/91	R&D figures not available (re-organization in progress)			
1991/92	47	77	24	148
1992/93	48	79	24	151

Comments:

There is currently a staff of five at Prince George including three persons who are involved with R&D, of whom one is a research scientist. The two others are forestry officers involved directly in research activities. It is projected that the staffing level at Prince George will increase by 2 py's in 1992/93. All but one position at Prince George are funded by the Green Plan.

5.a Principal Criteria for Success

The principal criteria of success for individual scientists are achievement of advances in human knowledge which can be applied to promoting *"the sustainable development and competitiveness of Canada's forest sector"*, and refereed publications.

For the Centre as a whole success is based on finding solutions to technical and scientific problems in the forest sector and seeing these solutions implemented to improve forest management.

5.b Most Successful Projects

1. The Pinewood nematode has reduced the level of exports of Canadian wood products to Europe, and threatens to lower the levels even further. Forestry Canada has conducted research aimed at controlling the nematode, and has funded the development of control methodologies.
2. Research on the remote sensing of soil compaction has led to improved methods for quantifying environmental impacts where heavy vehicles are involved. A licensing/patenting process is under way. Soil disturbance measurements and long term growth data have been combined to develop the Interim Forest Harvesting Guidelines for the B.C. Interior.
3. Functional pest management systems for Douglas-fir beetle, Douglas-fir Tussock moth, Douglas-fir seed orchard pests, nursery diseases and dwarf mistletoes were developed and have been implemented in B.C.
4. Spread, hazard rating and population dynamics models for mountain pine beetle developed at the Centre are used in operational forest management planning and for evaluating the B.C. Ministry of Forests' control program.
5. The Canadian Forest Fire Danger Rating System, developed jointly with other Forestry Canada research organizations, is used operationally throughout B.C. and Canada as well as in many other areas of the world.
6. Survey of forest insect and disease conditions in B.C. and the Yukon.

6.a Patents, Technical Papers and Citations

No patents are active at this time.

Booklets listing publications for the years 1986 to 1990 were provided and are on file in the PACST library. The 1990 lists publications in the following areas (number of publications in brackets): Biology/Immunology (7), Ecology (4), Entomology (13), Environment (4), Forest Insect and Disease Survey (8), Fire (4), FRDA (21), Inventory/Growth and Yield (3), Pathology (9), Pest Identification (1), Remote Sensing and Mensuration (2), Silviculture (4), Soil (8), Taxonomy (2), Vegetation Management (7).

6.b Spin-off Companies

An extensive list of products already commercialized and products ready for commercialization was provided. This list is on file in the PACST library. Some

highlights have been extracted and included as a part of the responses to questions 6b and 6c.

Forest Technology Systems (FTS) of Victoria was formed in the late 1970's to commercialize prototype automatic remote fire weather stations developed by the PFC. In the early 1980's the Canadian Forest Service and DSS assisted FTS in the development of telemetry for the stations. There are now over 1000 systems in use across Canada, and sales programs in the U.S. and Australia are under way.

Safer Agro Chem Ltd. (now Safer Ltd.) was founded to commercialize the discovery at PFC that fatty acid salts were useful as safe, effective pesticides. Today, Safer employs 65 people with 27 in R&D. Safer has also commercialized a PFC-developed treatment to prevent infestation of logs and trees by ambrosia and bark beetles.

6.c New Products Resulting from Research

No data on employment or sales is readily available, but commercialized developments include a styroblock reforestation systems which is estimated to save $23 million p.a. in B.C. in reseeding costs, an aerial fire ignition systems (for initiating desired burn-off), and an expert system for nutrient deficiency diagnosis and treatment

6.d Intangible Benefits

PFC staff believe they have played an important mediation role between the major forestry companies in B.C. and forest preservationists.

Methods developed at PFC for determining productivity losses from harvesting and site preparation operations have been written into B.C. Forest Service manuals.

Photoperiod lighting techniques developed at PFC are now applied throughout B.C. nurseries to grow over 100 million seedlings a year, worth approximately $13.5 million. Special low cost techniques for growing high-elevation tree species have also been developed and adopted.

A scientific data base has been developed and used to plan expenditures of $35 million on juvenile tree spacing and fertilization.

Other examples include many forest pest management systems, insulated seedling truck canopy, and systems for the protection of the forest environment.

6.e Outstanding Research Scientists Attracted to B.C.

None listed.

6.f Benefits to Provincial R&D Establishments

The PFC works very closely with the B.C. Ministry of Lands and Forests, and particularly with the group involved in forestry research. It also works with B.C. universities and with forestry company research organizations. Contracts to B.C.

universities amounted to approximately $1.4 million from 1985 to 1991 (under the FRDA I funding program).

7. Important Collaborative Organizations

Many organizations are important, depending on the research project in question. The B.C. forest industry, the B.C. Ministry of Lands and Forests, other Forestry Canada research centres and the U.S. Forest Service research groups get particular mention.

8. Suggestions on Ways B.C. Might Derive Greater Value from the Work at This Establishment

No specific suggestions.

9. Industry Overview

A variety of articles and booklets providing forest industry statistics were provided. These have been listed in 10 below and are stored in the PACST library. (A statistical overview has been written as a part of the overview.)

10.a Recent Publications

The following documents have been deposited in the PACST library:

1. *Forestry Canada Annual Report, 1988-89* - A 19 page annual report.
2. *Forestry Canada - Pacific and Yukon Region Strategic Plan, 1991-1995* - A 27 page summary planning document stating objectives and outlining programs, but not providing any details on implementation.
3. *Economic Forestry Statistics, 1989* - A 325 page Forestry Canada (B.C. and Yukon Region) report providing computer printouts of a large range of production and use statistics running in many cases from the early 1960's to the late 1980's.
4. *British Columbia Forest Industry Fact Book, 1989* - A 55 page fact book published by the Council of Forest Industries of B.C. (photocopy).
5. *Reports and Publications, Pacific and Yukon Region* - A series of five documents from 1986 to 1990 inclusive. Each document contains about 8 pages of listings. In addition there is a small booklet listing reports published under the Canada-British Columbia FRDA, dated November, 1991.
6. *Canada-British Columbia Partnership Agreement on Forest Resource Development: FRDA II: 1991-1995* - A 25 page booklet containing the FRDA agreement which involves the expenditure of $200 million over five years, jointly funded by the two levels of government. $11.6 million of the total is earmarked as a federal contribution to "Research in Sustainable Forest Development".
7. *Commercialization of Forestry Canada Research Findings from the Research Program of the Pacific Forest Centre* - An 8 page typewritten memo listing products already commercialized and others ready for commercialization. The memo is undated, but is suspected to date from early 1990. The list makes interesting reading. Some parts of it were extracted and included in the response to questions 6b, 6c and 6d above.

8. *Various Brochures* - A variety of different brochures providing public information about forestry in B.C. and about the activities of Forestry Canada.

10.b Key Scientific or Technical Papers

All publications are listed in Reference No. 5 above. Some key papers which relate to projects mentioned are:

1. Pollard, D.F.W., "Forestry in British Columbia: planning for future climate today", *For. Chron. 76(4):336:341*, 1991

2. Safranyik, L; Silversides, R; McMullen, L.H.; Linton, D.A., "An empirical approach to modelling the local dispersal of the mountain pine beetle *(Dendrocionus ponderosae* Hopk.) (Col., Scolytidae) in relation to sources of attraction, wind direction and speed", *J. Appl. Entomol. 108:498-511*, 1989.

3. Futai, K.; Sutherland, J.R., "Pathogenicity and attraction to host extracts of Canadian pinewood nematodes: studies with Scots pine, western larch and black spruce seedlings", *Can.J.For. Res. 19:1256-1261*, 1989.

4. Wood, C.S.; Van Sickle, G.A., "Forest insect and disease conditions in British Columbia and Yukon, 1989", *For.Can.Pac.For.Cent.Inf.Rep. BC-X-318*, 1990, 28pp.

5. Thomson, A.J.; Taylor, C.M.A., "An expert system for diagnosis and treatment of nutrient deficiencies of Sitka spruce in Great Britain", *AI Appl.Nat.Res.Manage. 4(1):44-52*, 1990.

6. *Development and Structure of the Canadian Forest Fire Behavior System*, Forestry Canada Fire Danger Group, Forestry Canada publication (in press)

7. *Canadian Forest Fire Danger Rating System - User's Guide*, Canadian Forest Service Fire Danger Group publication, 1987.

11. Major Projects

Some material related to projects in Forest Ecosystems Dynamics, Carbon Nutrient studies, Stem Rusts and Pathogen management was supplied to provide examples of the type of projects being undertaken. This information is stored in the PACST library.

CHAPTER 9 - THE DEPARTMENT OF NATIONAL DEFENCE

9.1 General Overview

The Defence Research Establishment, Pacific (DREP) at Esquimalt has been in operation since 1948, and currently employs 130 persons, 49 of whom are defence scientists. About 50% of the work is classified in nature, with the emphasis of the research being in mine counter-measures, underwater electromagnetic surveillance (magnetic anomaly detection (MAD)), underwater acoustic surveillance in the Arctic and the Pacific, and some aspects of materials technology. The annual budget in 1991/92 was about $14.2 million including salaries but excluding the cost of operating the research vessel.

An important part of DREP's mission is to contribute to the growth of the defence-related science and technology base in Canadian universities and in industry. In 1991/92 outside contracts amounted to $3.6 million, about 73% of which went to B.C. industry and 27% to B.C. universities. Some of these contracts have had an important impact, notably those to Professor Barrodale at the University of Victoria which led directly to the establishment of Barrodale Computing, and to ISER Ltd. of Port Coquitlam for the development of two autonomous underwater vehicles (ARCSS and DOLPHIN), whose potential markets are estimated to be substantial, though as yet largely unrealized.

Two contracts in the fields of underwater surveillance have led to sales in the $50-$100 million range. In these instances, neither of the companies involved, Computing Devices of Canada and CAE Electronics, are based in B.C.

The establishment has the use of the *CFAV Endeavour*, a 75-metre Department of National Defence research vessel commissioned in 1975. The ship is crewed by civilians but the operating costs are covered by the Queen's Harbour Master. The *Endeavour* is also used by the Institute of Oceanographic Studies, universities, and other Chief Research and Development (CRAD) laboratories.

9.2 The Defence Research Establishment, Pacific

1. Address

FMO Victoria, Victoria, B.C., V0S 1B0

Address

Dr. Todd Garrett, Chief of the Establishment (363-2867)
Dr. Robert Chapman, Director of Physics Research (363-2906)
Mr. S. E. Forshaw, Head, Plans and Programs (363-2868)

Fax: (604) 363-2856

2. Mandate/Objectives

DREP is the lead CRAD Laboratory providing defence scientific and technological expertise to the Canadian Forces (CF) and DND in:

- Mine countermeasures
- Underwater low-frequency surveillance in the Arctic and Pacific;
- Air-related materials technology;
- Aspects of marine and land materials technology.

In carrying out its mission DREP provides scientific and technical advice, assistance, and operational support to the CF and DND. It also conducts and sponsors defence R&D; advances and exploits key technologies through national and international collaboration; and contributes to the development and maintenance of a defence industrial capability.

DREP is committed to providing responsive, knowledgeable and cost-effective service; advancing the state of the art in its areas of technical responsibility; and recognizing its environmental responsibilities. It is also committed to maintaining quality, integrity and professional responsibility and developing the skills, expertise and well-being of its employees.

3. Budgetary Information (in thousands of dollars, excluding salary costs)

Year	Operating	Contract	Capital	Total
1988/89	$2,126	$2,947	$3,293	$8,366
1989/90	$2,612	$5,330	$4,200	$12,142
1990/91	$2,396	$4,384	$3,678	$10,458
1991/92	$2,512	$3,608	$2,087	$8,207
1992/93	$2,650	$3,800	$2,000	$8,450

Comments (including source of funds):

1. The total cost is the sum of operating, contract and capital costs, and does **not** include salary costs (though benefits are included).

2. In 1991/92 salary costs were approximately $6 million.

3. The cost of operating the research vessel (which is not exclusively used by DREP) is not included in any of the above figures.

4. Person years

Year	Defence Scientists	Scientific Support	Admin.	Total
1988/89	51	44	37	132
1989/90	51	44	37	132
1990/91	51	44	37	132
1991/92	50	43	37	130
1992/93	49	44	37	130

Comments

1. The average cost of a person year (salary only) is estimated at about $47,000.
2. In addition to the above figures, approximately 6 co-op students and 15 summer students are employed annually at an average salary of about $2,100 per month. In 1991/92 this amounted to an additional 5.5 PYs.

5.a Principal Criteria for Success

Ten indicators are used to assess the performance of DREP activities:

1. Pre-approval by the CF and influential defence committees, particularly of major initiatives;
2. Participation in systems studies involving personnel from the CF and other CRAD establishments to define objectives and anticipated results;
3. Participation in experimental developments and demonstrations through to production and utilization by the CF;
4. Spin-offs that are useful to the CF and/or industry;
5. Cooperation with industry and universities, and laboratories in allied countries;
6. Ability to respond to national emergencies in concert with industry, other CRAD establishments, and allied forces;
7. Number of refereed scientific publications;

8. Number of patents;
9. Invitations to contribute to national/international science and technology meetings and studies;
10. Sponsored Defence Industrial Research Program (DIRP) projects.

5.b Most Successful Projects

Automatic integrated MAD system (AIMS)
Electromagnetic ship signature-reduction system
Engine health monitoring (EHM)
Centrifugal reverse osmosis system
Matched field processing (MFP)
Repair adhesives
Delamination fracture mechanics evaluation of composite materials
Ultrasonic boiler inspection system (UBIS)
Chromate-free primer paints
Torpedo Otto fuel detector
Signal processing and imaging software for ultrasonic testing of composites (SPUD)

6.a Patents, Technical Papers and Citations

Although DREP keeps these records, they are not compiled centrally and we are unable to provide these lists at this time.

6.b Spin-off Companies

DREP was responsible for the formation of Barrodale Computing Service and CTF Systems and has also contributed to the growth and viability of the following companies:

- ISE Research
- Sea-I Research
- Off-Shore Systems Limited
- RE TECH
- JASCO
- Davis Engineering
- Lambda Technology
- HI-TECH Systems

All are B.C. companies, except Davis Engineering which is from Ontario.

6.c New Products Resulting from Research

The products listed below have been sold by B.C. and non-B.C. companies. AIMS and CANTAS are realizing revenues in the $50M-$100M range, and the ARCSS system has the potential for similar revenues. Estimates of actual and/or potential revenue for the other products listed, and their impact on employment, are not readily available.

- AIMS
- Canadian towed array systems (CANTAS)

- Arctic surveillance systems (ARCSS): several companies are presently bidding on the definition study.
- Electromagnetic ship signature-reduction system: Davis Engineering
- Ferroscan engine health monitoring system: SENSYS and GASTops Ltd. both from Ontario.
- Centrifugal reverse osmosis system: Hi-Tech Enterprises.
- Luomapoxy adhesives: Industrial Formulators of Canada, a B.C. company.
- Ice blasting for paint removal: RE TECH Ltd.
- UBIS: CTF Systems Inc. and Lambda Technology.
- Chromate-free primer paints: Industrial Science Laboratories of B.C.
- Torpedo Otto fuel detector: RE TECH Ltd.
- SPUD: Barrodale Computing Services
- Medical and geophysical gradiometers: CTF Systems
- Improvements to the ARCS and DOLPHIN undersea vehicles: ISE Research.
- Improvements to the MANTA undersea vehicle: Sea-I Research.

6.d Intangible Benefits

DREP has participated in two international environment studies, the Heard Island Experiment which measured the velocity of sound over long propagation paths, and hence ocean temperature and indications of global warming; and rain water monitoring for indications of increases in radioactive fallout from nuclear accidents.

6.e Outstanding Research Scientists Attracted to B.C.

DREP's policy has been to hire science/engineering graduates from the top 25% of the class and develop them internally. Approximately 15% of DREP's scientists demonstrate the high rate of professional development expected of outstanding research scientists.

6.f Benefits to Provincial R&D Establishments

- Employment of approximately 15 summer students per year;
- Employment of approximately 6 co-op students per year;
- Support and supervision of up to two graduate students at UVic, up to two at UBC, and up to two at RRMC;
- Four adjunct professors at UVic and UBC;
- Contracted research at UVic, SFU, and UBC. For example, from 1989/90 to 1993/94 this amounts to $63,000 at UVic and $940,000 at UBC.
- Development of a significant composite materials capability at UBC through research funding.

7. Important Collaborative Organizations

The following are most important to DREP in terms of collaboration:

- Barrodale Computing Services
- Sea-I Research
- JASCO Research Limited
- ISE Research
- UBC
- MacDonald Dettwiler

- RE TECH
- Industrial Formulators
- Davis Engineering
- Galatea Research
- CTF Systems
- Crystar Research
- Polymer Engineering
- Lambda Technology
- National Research Council
- Institute of Oceanographic Studies
- Pacific Geoscience Centre

8. Suggestions on Ways B.C. Might Derive Greater Value from the Work at This Establishment

The principle means whereby the B.C. research and industrial development community might derive greater value from our work is through the Defence Industrial Research Program as described in Document 2. (See 10.a below).

DREP routinely contracts out about $4M per year in research contracting, 75% of which goes to B.C. industry and universities.

9. Industry Overview

The main disciplines in which DREP works include physics, chemistry, electrical engineering and mechanical engineering. In these combined areas DREP expended approximately $5.8M in FY 1991/92.

10.a Recent Publications

The following documents were provided and are on file with PACST:

1. *Defence Research Establishment, Pacific* - a six page document outlining laboratory activities and showing pictures of various experimental apparatus and activities.
2. *Defence Industrial Research Program* - a 22 page booklet describing the program and providing instructions on how to apply.

10.b Key Scientific or Technical Papers

Copies of the following papers were provided and are on file with PACST:

1. "One-Way Seismo-Acoustic Propagation in Elastic Waveguides with Range-Dependent Material Parameters", *Computational Acoustics 3*, 1990, pp. 275-288.
2. "Improving Performance for Matched Field Processing with a Minimum Variance Beamformer", *J. Acoust. Soc. Am. 91(1)*, January 1992, pp. 141-150.
3. "Transient Scholte Wave Transmission Along Rough Liquid-Solid Interfaces", *J. Acoust. Soc. Am. 83(4)*, April 1988, pp. 1336-1344.

4. "Estimation of the Elastic Properties of Sea Floor Sediments", Proceedings of Oceans '89, *IEEE 89CH2780-5*, Sept. 1989.

5. "Acoustic Scattering in a Three-Dimensional Oceanic Waveguide Using Boundary Integral Equation Methods", *J. Acoust. Soc. Am. 90(5)*, Nov. 1991, pp. 2609-2622.

6. "Comparison Between Measured and Theoretical Results for C- and K_u-Band Backscatter from Naturally Occurring Internal Wave Current Patterns", *IGARSS '89*, pp. 2014-2023.

7. "A Boundary Integral Equation Method for Acoustic Scattering in a Waveguide with Nonplanar Surfaces", *J. Acoustic Soc. Am. 87(3)*, March 1990, pp.1110-1125

8. Combining GC/IR and LC/IR to Determine Compositional Changes Associated with Aging in Acrylic Structural Adhesives", *J. Chromo. Sci.* 24, May 1986, pp. 210-215.

9. "Coated Piezoelectric Quartz Crystal Monitor for Determination of Propylene Glycol Dinitrate Vapor Levels", *Analytical Chem.* 57, Sept. 1985, pp.2120-2124.

10. "A Comscan Investigation of Glass-Reinforced Plastic/Foam Sandwich Material", *Proceedings of 2nd International Conference on Sandwich Construction*, 1992

11. "Initiation and Growth of Mode II Delamination in Toughened Composites", *Am. Soc. for Test. & Materials 1110*, 1991, pp. 226-242.

12. "Development of an Automated Ultrasonic Inspection System for Composite Structure on In-service Aircraft", AGARD Conference Proceedings 462, *Impact of Emerging NDE-NDI Methods on Aircraft Design, Manufacture and Maintenance*, 1989, pp. 13.1-13.13.

13. "Fatigue Crack growth in Adhesively Bonded Graphite/Epoxy Joints under Shear Load", *Adv. in Adhesively Bonded Joints 6, AMSE*, 1988, pp. 87-92.

14. "Specimen Size and Orientation Effects on the Toughness of Steel Weldments, *Trans. of ASME 111*, July 1990, pp. 270-277.

15. The Determination of Instrumented Impact Machine Compliance Using Unloading Displacement Analysis", *Experimental Mechanics* Vol 29, June 1989, pp. 152-156.

16. "Orientation Dependence of Fracture Toughness in 8090 Aluminum Alloy Plate Using Chevron Notched Specimens", *8th European Fracture Conference*, October 1990.

11. Major Projects

1. Ocean Physics

Project Resources 1992/93: Budget $2.0M, PY 38.

This work is aimed at obtaining an understanding of low-frequency sound propagation and ambient noise in the North-East Pacific and Arctic Oceans with the objective of detecting submarines by acoustic methods. The understanding gained is applied to the development and evaluation of modern sonar signal processing methods in estimating

the performance of future sonars through simulation and modelling, and in the development of sonar systems. Tests and measurements with experimental equipment at sea and during field trials form a large part of the activity.

The eastern half of the subarctic North Pacific Ocean (north of 40^0 north latitude) has a number of unique oceanographic properties which have a major impact on sound propagation, and hence on sonar performance. The dominant acoustical feature which makes it different from most other ocean areas is the presence of two relatively shallow sound channels. These trap acoustic signals and allow propagation to very long ranges with little energy loss.

A primary tool in the study of these features is a horizontal towed array known as the Canadian Ocean Measurement System (COAMS) which consists of a set of four nested sub-arrays of hydrophones some 2 km in length. The knowledge obtained with this array and other acoustic systems has enabled the development of realistic propagation and detection models, target tracking algorithms, and matched field processing techniques. All of this has led to a capability to estimate the performance of future sonars, formulate new signal processing methods, and to advise on and develop advanced submarine detection systems.

Both underwater ambient noise and sound propagation conditions in the Arctic differ considerably from those in the open ocean. In the winter and spring, when the channels are covered with stationary, shore-fast ice, the ambient noise levels are very low. Most noise produced during this period is either biological in origin or is caused by ice cracking and wind-driven snow. During the periods of break-up and freeze-up ice floes grind together and wind-generated surface waves result in high noise levels.

In the Arctic Basin the ice floes are continually moving and grinding together, even in winter and spring. As a result the seasonal changes in noise levels are less pronounced than in the channels. The unique acoustics of the Arctic provide an interesting challenge to the sonar designer and operator.

Considerable creativity has been required in living and working in the Arctic environment. Techniques have been developed for drilling through up to 50 m of ice to deploy hydrophones, and for laying cables through the ice and shore interface where the moving ice scores the sea bed.

DREP's major R&D links are through The Technical Co-operation Program (TTCP), an agreement between Australia, Canada, New Zealand, the U.K. and the U.S.A to share defence research and development encompassing pure and applied research and exploratory development. In this project, areas of TTCP linkage include sonar technology and undersea warfare studies.

2. Electromagnetics

Project Resources 1992/93: Budget $3.3M, PY 25.

The steel parts of a submarine generate a small but detectable perturbation in the earth's magnetic field. A sensitive magnetometer mounted in an aircraft can measure this signal. Activities over many years have centered on developing a database of magnetic field data, developing signal processing algorithms, and performing simulation studies for the development of target detection and tracking tactics.

The present generation of MAD systems measure the strength of the total field, thus providing an indication of a submarine's presence. DREP is working on a superconducting magnetic gradiometer which will provide information on a submarine's range and bearing. The recently discovered high-temperature superconductors may facilitate this work.

Both the acoustic and electromagnetic characteristics of ships play a large role in mine warfare. Indeed, it is the detectability of the resulting signals that cause modern, non-contact mines to detonate as a ship passes nearby. Research to date has developed several methods of reducing electromagnetic signals of warships to levels below the mine detonation threshold.

To counter the possible threat of mines laid in Canadian waters, investigations are directed at various methods of searching the sea bed along shipping routes on the continental shelf. These activities include work on sophisticated towfish-mounted sonars for scanning the sea bed, precision navigation systems to determine the position of a mine sighting, remotely operated vehicles to search a suspected minefield, and high speed data processing and advanced acoustic image display and comparison systems to sort out the mines from the background clutter.

DREP's major R&D links are through TTCP and include airborne sensor technology, and mines and mine countermeasures technology.

3. Materials Technology

Project Resources 1992/93: Budget $2.3M, PY 30.

Materials Technology research is directed at developing and maintaining a technology base in chemistry, metals, composites, and non-destructive evaluation that is of direct relevance to the present and foreseen operational requirements of the CF in the solution of day-to-day problems arising with equipment and operations.

Chemistry-related studies include advanced adhesives, less toxic primer and anti-fouling paints, improved paint-removal methods, biodegradable plastics, methods for engine health monitoring, and structural ceramics. Studies of metals are directed at corrosion prevention and improving the fracture and fatigue resistance of new alloys offering improved strength-to-weight ratios for ship and aircraft applications.

For support of the composite materials used in modern military aircraft and helicopters, research is aimed at predicting the criticality of defects such as delaminations and disbonds, and in developing new materials, techniques and analytical approaches for structural repairs. In addition, advanced non-destructive evaluation methods such as robotically controlled ultrasonic inspection and computer-assisted real time radiographic inspection are being applied to the maintenance of aircraft composites.

DREP's major R&D links are through The Technical Co-operation Program. In this project, areas include metallic, ceramic, and organic materials, materials performance in systems, and non-destructive evaluation.

CHAPTER 10 - THE NATIONAL RESEARCH COUNCIL

10.1 General Overview

The National Research Council has a commanding presence in astronomy in B.C., which is the home of the Dominion Astrophysical Observatory just outside Victoria, and the Dominion Radio Astrophysical Observatory just outside Penticton. Both groups are a part of the Herzberg Institute of Astrophysics (HIA) which is headquartered in Ottawa. In addition, NRC carries out engineering research from two locations adjacent to the U.B.C. campus in Vancouver.

Negotiations are currently underway between NRC management and the B.C. government concerning the transfer of the rest of the Herzberg Institute of Astrophysics from Ottawa to a new building on the University of Victoria campus. The Council is also considering a plan which could see the two Vancouver-based engineering groups merged with others to form a substantial new engineering institute which it would plan to house in the old Forintek building adjoining the U.B.C. campus.

The move of the Ottawa sections of the Herzberg Institute to Victoria would involve the transfer of approximately 80 scientists and technicians.

Should a new engineering institute be formed in Vancouver it could eventually involve approximately 95 additional NRC scientists and supporting staff, and up to 40 research associates, collaborators and guest workers. It is anticipated that NRC expenditures at the new institute would be about $7.5 million p.a., which would be a significant increment to Federal research expenditures in B.C.

The budgets of the four NRC laboratories for 1991/92 were as follows:

Facility	Est. Annual Budget($000) Internal Funds	Ext. Revenue	Person Years Scientists	Person Years Total
Science				
DAO	$3,750	$300	11	41
DRAO	$2,636	?	7	28
Engineering				
Tribology	$1,325	$200	6	18
Info. Tech.	$900	$75	4	10
TOTAL	**$8,611**	**$575**	**28**	**97**

The *Dominion Astrophysical Observatory* (DAO) was inaugurated in 1918 and has since made major contributions to our understanding of the universe. The original 1.8 m reflecting telescope, continually upgraded over the years with first class instrumentation, is still a useful device with heavy demands for observing time from astronomers around the world, particularly for the observation of rapidly changing phenomena which require a large number of viewing days. A second reflecting telescope (1.2 m) was added at the site in 1962. It too is heavily booked.

The early fame of the observatory rested on the study of binary stars, and the first accurate mapping of the Milky Way galaxy. Work is continuing in these fields, as well as in studies of super massive black holes, bright star clusters, and dark matter - the elusive missing mass which is known to be there because of its observed gravitational effect, but which is otherwise undetected and certainly not yet understood.

Laboratory scientists also participate in experiments and instrumentation development related to the Canada France Hawaii Telescope (CFHT), a 300 ton 3.6 m reflecting telescope at the summit of Mauna Kea, an extinct 4,200 m volcano on the island of Hawaii, which is believed to be the best terrestrial viewing site in the world. It is also very actively involve in planning for Canada's participation in the two 8 m Gemini telescopes, one to be located in Chile to view the southern hemisphere and one at Mauna Kea. If this project proceeds as expected, DAO will house the Canadian project office for the venture.

The *Dominion Radio Astrophysical Observatory* (DRAO) is located in a valley surrounded by low mountains, about 20 km south-west of Penticton. The site was selected in 1958 because of the protection it provides against man-made emission, and is one of the best sites in North America for radio astronomy at centimetre wavelengths.

DRAO operates two major radio telescopes as national facilities, a (recently upgraded) seven element aperture-synthesis telescope and a 26 metre single reflector telescope. The observatory also operates solar radio telescopes whose data is made available as a service to the scientific and technical community.

Much of the effort of all staff is devoted to running the facility for outside experimenters from Canadian universities and elsewhere.

The instruments at the DRAO site have found their greatest use in the study of interstellar matter in our own (Milky Way) galaxy because of their ability to make images of large regions of very faint, extended radio emissions. The solar radio program has recently been transferred from Ottawa to Penticton, continuing a world acclaimed 40 year series of important basic solar flux measurements and of research into the mechanisms at work in the sun. The solar data is also used for investigations of the Earth's upper atmosphere, and for studies of climatic change.

The two engineering groups currently operating in Vancouver are the *Tribology Mechanics section of the Institute of Mechanical Engineering*, and the *Systems Laboratory*, formerly a part of the Institute of Information Technology, and now associated with Mechanical Engineering.

The *Tribology Mechanics* group has been in existence in Vancouver since 1972. It's focus is on applied studies in tribology (friction) and mechanics aimed at solving major generic and some specific problems faced by Canadian industry. Perhaps its greatest research success has been its work on rail wear, which is estimated to save the Canadian railways approximately $100 million p.a. Other projects include studies of braking problems on the Canadarm (in space), noise reduction associated with the Vancouver Skytrain, the development of a log yarding system, and a variety of other theoretical and practical friction studies.

The *Systems Laboratory* of the Division of Mechanical Engineering was created in 1987 with the objective of focusing on information technology of relevance to the resource and transportation industries. Since that time it has broadened its clientele and perspectives and focuses on the development of practical applications of "Symbiotic Systems" software and object-oriented programming.

10.2 Dominion Astrophysical Observatory, Herzberg Institute of Astrophysics

Overview

It is surprising, and a little bewildering, for the layman to discover just how many different kinds of stars and other phenomena there are in our universe, all bred from basic matter which is essentially similar. It is the task of the astrophysicist to observe these phenomena and to attempt to understand how they came about. In order to do so, a variety of telescopes are deployed which work at a range of varying electromagnetic frequencies from the radio bands through the infrared, the familiar optical bands, and on into the ultraviolet range and beyond (where observations are best made from space platforms such as the Hubble Space Telescope).

The deeper into space the astronomers probe, the higher is the resolution required of the observing instruments, and the larger and more expensive they tend to become. But there is also a revolution underway in optical detectors and in the processing of the weak optical signals detected in these giant instruments, driven by the same developments in microelectronics which are having such a profound effect on the rest of the world. Dominion Astrophysical Observatory (DAO) physicists, working with university-based astronomers, have been world leaders in the development of some of these instruments.

DAO was inaugurated in 1918 and has since made major contributions to our understanding of the universe. The original 1.8 m reflecting telescope, continually upgraded over the years with first class instrumentation, is still a useful device with heavy demands for observing time from astronomers around the world, particularly for the observation of rapidly changing phenomena which require a large number of viewing days. A second reflecting telescope (1.2 m) was added at the site in 1962. It, too, is heavily booked.

The early fame of the observatory rested on the study of binary stars, and the first accurate mapping of the Milky Way galaxy. Work is continuing in these fields, as well as in studies of the extragalactic distance scale; super massive black holes; star clusters; and dark matter - the elusive missing mass which is known to be there because of its observed gravitational effect, but which is otherwise undetected and certainly not yet understood.

Canada has a 42.5% interest in the Canada France Hawaii Telecsope (CFHT), a 300 ton 3.6 m reflecting telescope at the summit of Mauna Kea, an

extinct 4,200 m volcano on the island of Hawaii, which is believed to be the best terrestrial viewing site in the world. Canada's involvement in this spectacularly successful instrument is supported by DAO. A major factor in the success of the CFHT has been the development of electro-optic instrumentation which compensates for time-varying atmospheric distortions of the received light. This instrumentation was the result of a co-operative project between astronomers at the University of Montréal and at DAO.

The two 8 m Gemini telescopes, one to be located in Chile to view the southern hemisphere and one at Mauna Kea, are now in the advanced stages of negotiation. It is proposed that Canada would have a 15% interest in these instruments, sharing ownership with the U.S. (50%) and Britain (25%)[1], at a capital cost to Canada of $38 million. DAO supported preliminary design studies for Gemini and, if this project proceeds as expected, DAO will house the Canadian project office for the venture.

As one would expect, an important pastime for astronomers is the comparison of viewing results from a particular segment of the sky with what has been detected at other frequencies by other telescopes. DAO houses the Canadian Astronomy Data Centre (CADC) which provides astronomical data archives and processing software to users across Canada. It is an official centre for the distribution of data from the Hubble Space Telescope. In large measure because of these responsibilities, it has been a leader in the development of CAnet, the Canadian scientific data communications network of which BCnet was one of the founders.

An important industrial spin-off from all this research activity has been the positioning of Coast Steel Fabricators of Port Coquitlam as world leaders in the supply of astronomical dome enclosures and telescope construction. This position was initially established through the company's work on the CFHT dome in the late 1970's. DAO also works with several other B.C. and Canadian companies in the fields of optics and electronics.

DAO currently employs 41 people at the Victoria site, 14 of whom are astronomers. Its annual budget, including capital expenditures of about $250 thousand, is about $3.8 million.

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[1] The remaining 10% is yet to be determined.

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2. **Mandate/Objectives**

The NRC Act includes the authority "to operate and administer any astronomical observatories established or maintained by the Government of Canada". The Herzberg Institute of Astrophysics (HIA) has the responsibility for implementing this mandate.

The objectives of the DAO program within the HIA are to provide expertise and support for optical, infrared, and ultraviolet astronomy in Canada by:

- Operating optical telescopes and facilities for use by the astronomy community;
- Designing and developing optical telescopes and their instrumentation to meet the needs of the astronomy community;
- Developing computer systems and programs for data processing and analysis, and for the collection and distribution of archival data;
- Maintaining a core of scientific and engineering expertise in optical astronomy;
- Supporting the scientific infrastructure, and providing public information.

The Dominion Astrophysical Observatory operates the DAO telescopes as a national facility; develops instrumentation for the DAO telescopes, the CFHT, and other major telescopes such as the Lyman ultraviolet satellite and the proposed Gemini telescopes; operates the CADC which provides access to, and processing software for, astronomical databases, particularly that from the Hubble Space Telescope; and operates a major public information program, including visits to the DAO facility, that attract about 40,000 visitors a year.

3. **Budgetary Information (in thousands of dollars)**

Year	Operating	Est. Salaries	Ext. Rev.	Capital	Total
1990/91	$709.0	$2,460.0	$250.0	$201.0	$3,620.0
1991/92	$740.0	$2,460.0	$300.0	$254.0	$3,750.0
1992/93	$727.0	$2,460.0	$360.0	$244.0	$3,790.0

Comments (including source of funds)

1. External revenue includes funding from the Canadian Space Agency related to the Lyman satellite and for the Canadian Astronomy Data Centre (Hubble

telescope data), and instrumentation contracts from the Canada France Hawaii Telescope.

2. 1990/91 funding included about $70K for contracts to B.C. companies for engineering studies related to the proposed Gemini telescopes.

3. Salaries are estimated on the basis of an average $60K per person year irrespective of inflation.

4. Person years

Year	Research Scientists	Scientific Support	Admin.	Total
1988/89	11 + 2	22	6	41
1989/90	11 + 2	22	6	40 + 1
1990/91	11 + 2	22	6	40 + 1
1991/92	9 + 2	25	5	40 + 1
1992/93	10 + 4	23	5	39 + 2

Comments

1. The Research Scientist column is divided into permanent research staff (the first and larger figure in the column), and post-doctorate research associates, some of whom are foreign.

2. Total numbers include term employees, but do not include students. At any given time there are approximately 50 people working on site, of whom about five are guest workers and the remainder are co-op or summer students.

3. The government is slowly moving away from separate operations and person-year budgets. Those departments which have outside revenue are permitted to employ so-called "revenue person-years" with the funds they obtain. These are shown separately in the Total column. For example, in 1992/93 two revenue person-years are planned, up from one the year before. In DAO's case, the revenue py's are paid for out of CFHT contract income.

4. In addition to the totals mentioned above, it is anticipated that there will soon be up to two more persons on site associated with the Canadian Gemini Project Office which will be centred at DAO.

5.a Principal Criteria for Success

1. Scientific excellence as measured against international competition.

2. Excellence in the development of unique instrumentation and data archiving techniques.

5.b Most Successful Projects

In general, DAO's strengths have been in the astrophysical research of stars, stellar populations in galaxies, the extragalactic distance scale, active galaxies, and large scale structure in the universe. DAO's scientists have won a number of prestigious national and international prizes for their work.

Noteworthy scientific projects include:

- Ultraviolet spectroscopy results from the Hubble Space Telescope have uncovered a site of extraordinary star formation which began only three million years ago.
- The spiral galaxy NGC 4571 in the Virgo Cluster has been resolved into stars with the High Resolution Camera (HRCam) at CFHT by M. Pierce, R.D. McClure (DAO) and R. Racine (U. de Montréal). Consequently it now appears possible that one of the so-called key projects, which it was thought could only be done once the Hubble Space Telescope was repaired, can be done from CFHT with HRCam. Preliminary analysis of the resolved supergiant stars suggests the distance to the galaxy is about 14 Mpc, thereby favouring higher values of the Hubble constant.
- Observations of unprecedented angular resolution of quasars taken with the HRCam at CFHT have shown that the enormously energetic phenomena characteristic of these objects are activated by the merging of massive galaxies with smaller ones.

Particularly successful instrumentation projects include:

- High resolution camera for the Canada France Hawaii telescope (CFHT) (with René Racine of the Univ. of Montréal)
- Optical designs for the CFHT and the Lyman satellite
- Implementation of the Canadian Astronomy Data Centre and contributions to CAnet
- Development of an internationally adopted stellar photometry code (DAOPHOT).

6.a Patents, Technical Papers and Citations

A patent application for an innovative optical device, an atmospheric dispersion corrector, is underway.

Publications appearing in each year are listed in the relevant annual report of the HIA. The 1990/91 annual report lists 72 publications (pp. 25-27).

Records of citations are kept, and some scientific papers have been very heavily cited.

6.b Spin-off Companies

Not directly. Indirectly, DAO has been an important factor in the establishment of two science communications companies.

6.c New Products Resulting from Research

A number of industrial interactions are listed in the HIA annual reports (seven are listed on p.28 of the 1990-91 report). Figures on any new sales or employment which might have resulted from the interactions are not readily available.

Coast Steel Fabricators of Port Coquitlam have become the leading producer of astronomical enclosures, including that for the world's largest telescope (the Keck Observatory) primarily as a result of a contract to provide the enclosures for the CFHT in the late 1970's. Overall, business resulting from the first CFHT contract has since amounted to about $70 million, and it is still growing.

6.d Intangible Benefits

- A very active public information program (an estimated 40,000 visitors to DAO in 1991).
- About two major scientific meetings per year attract from 100 to 700 people per meeting, a substantial boost to the tourist trade.
- There are about 100 scientific/technical visitors p.a., some of whom stay for a considerable length of time.

6.e Outstanding Research Scientists Attracted to B.C.

Yes, many of the present staff at DAO (van den Bergh, Stetson and others) plus some members of the UVic faculty.

Lists of the distinguished scientists who spend all or part of their sabbatical at DAO can be found in the HIA Annual Report (31 names are listed for 1990/91).

6.f Benefits to Provincial R&D Establishments

1. Strong support of university faculty research through access to facilities (telescopes, library, computer-aided design, software, data reduction equipment, scientific collaboration).
2. About five graduate courses in astronomy given at UVic.
3. Graduate student supervision (two PhD's and three to four M.Sc's in the past five years).
4. Eight to ten co-op positions p.a. (scientific, computer science, technical)
5. Major contributions to the development of the university, industrial and scientific data communications network, CAnet.

7. Important Collaborative Organizations

UVic - Physics and Astronomy Dept.
UBC - Geophysics and Astronomy Dept.
Canadian Institute of Theoretical Astrophysics
U. de Montréal - Astronomy Department
U. de Laval - Astronomy Department

U. of Toronto - Astronomy Department
McMaster University - Physics and Astronomy Dept.
Engineering Departments, SFU and UVic.

8. Suggestions on Ways B.C. Might Derive Greater Value from the Work at This Establishment

1. Would very much like to see a resolution to the problem of moving the rest of the Herzberg Institute to Victoria (at an estimated cost of $8-$10 million).
2. Would like to see a program for industrial support of DAO instrumentation work, especially for the upcoming Gemini project.
3. Would like to see more support for the public information aspects of DAO's activities. Astronomy is a natural magnet for science education and present staffing levels preclude taking full advantage of the opportunities that DAO could provide.

9. Industry Overview

This question is not meant for an establishment like DAO which is not designed to support a particular industry.

An overview of astronomy research is given in an excerpt of the APPC report (see item 4 in the response to 10.1 below).

10.a Recent Publications

The following publications are stored in the PACST library:

1. *Annual Report of the Herzberg Institute of Astrophysics, 1990-91* - a 56-page report listing much useful information about the HIA, including DAO and DRAO in B.C.
2. *Herzberg Institute of Astrophysics - Annual Planning Review, 1992/93* - a 36-page planning document showing planned activities and priorities. (dated February 5, 1992)
3. *Annual Report of the Dominion Astrophysical Observatory for the Period 1 April 1990 - 31 March 1991* - a 13-page journal pre-print by G.C.L. Aikman and James E. Hesser outlining the scientific and instrumentation activities of the DAO, and providing a list of publications for the period. Journal offprints (from the *Bulletin of the American Astronomical Society*) for the previous two years are also available.
4. *Excerpts from the Report of the Astronomy Priorities and Planning Committee* (pp. 15-37), October 1991 - an excellent general survey of astronomy in Canada which outlines industrial ramifications.
5. *The Dominion Astrophysical Observatory - Window on the Universe; The Canada France Hawaii Telescope - Ten Years of Discovery; Les astronomes canadiens se préparent à sonder les profondeurs de l'espace . . .* - Three folders publicizing various aspects of DAO activity. The last of the three is in French and gives a brief description of the multi-national Gemini project (of which Canada is a member) to install two identical major telescopes, one in each hemisphere.

10.b Key Scientific or Technical Papers

Sources for lists of scientific and technical papers have already been given. Such lists are to be found in the documents listed in publications No.1 and No. 3 in the list of descriptive material to be found in the PACST library (see above).

Four of the most highly cited papers in recent years are:

1. Stetson, P.B., "DAOPHOT; A computer program for crowded-field steller photometry", *Pub.Astron.Soc. Pacific v.99*, p. 191, 1987
2. Hesser, J.E., Harris, W.E., VandenBerg, D.A., Allwright, J.W.B., Shott, P., and Stetson, P.B. "A CCD color-magnitude study of 47 Tucanae", *Pub.A.S.P.* vol. 99, p.739, 1987
3. Van den Bergh, S., McClure, R.D., and Evans, R. "The supernova rate in Shapley-Ames galaxies", *Astrophysical J. vol. 323*, p.44, 1987
4. McClure, R.D., et al., "Mass functions for globular cluster main sequences based on CCD photometry and stellar models", *Astrophysical J. Letters, vol. 307*, p.L43, 1986

11. Major Projects

A listing of projects including details of size, cost and duration was not provided; however the following excerpt from the 1990-91 HIA Annual Report (pp.21-23) gives a good idea of the scope of the programs under way.

Scientific Research

A superior new method for estimating the ages of star clusters in the halo of the Milky Way galaxy was devised by research associate Dr. M. Bolte and Dr. P. Stetson, with Prof. D.A. Van den Berg (UVic), thereby demonstrating that fundamental modifications must be made to the picture of the formation of the galaxy that has held sway since 1963.

J.B. Hutchings extended his major series of investigations into the morphological characteristics of quasars and active galactic nuclei. Working with S.G. Neff (NASA Goddard Space Flight Center), he produced observational evidence that quasars emitting significant radio emissions appear to live longer in the present epoch than they did in the early Universe. HRCam images of quasars from CFHT continue to reveal significant irregular structures near their nuclei.

M. West (CITA) and S. van den Bergh derived a spatial correlation scale length of $22h^{-1}$ MPC for galaxy clustering centered on cD galaxies. Such a value is too large to be compatible with conventional cold-dark-matter models of the Universe.

Hubble Space Telescope spectra obtained by J.B. Huthchings and his colleagues of a starburst knot in the galaxy NGC 1068 indicate that the initial mass function is truncated, so that stars older than 3 million years are inconspicuous.

A. Gulliver (Brandon U.), S. Adelman (The Citadel), C. Cowley (U. Michigan), and J.M. Fletcher have used high dispersion spectra with ultra-high signal-to-noise ratios (S/N =

2500) obtained with the 1.2-m telescope to study the bright star, Vega, in unprecedented detail. They find two distinct types of line profiles, which they suggest might be explained if Vega were a rapidly rotating star seen nearly pole on.

Instrument Development

Development of the Multiple Object Spectrograph/Sub-arc-second Imaging Spectrograph jointly with the Observatoire de Paris-Meudon proceeded on schedule under international project supervision of Dr. D. Crampton; the instrument should begin commissioning at the CFHT late in 1991 or early in 1992.

Modifications to the 1.8 m telescope drive system and the installation of a modified Newtonian focus for imaging with a charge coupled device were effectively complete by the end of the fiscal year, and extensive testing of the latter is planned for FY 91/92.

The f/4 coude echelle spectrograph for the CFHT is being developed under the direction of W.A. Grundman. A. Moore designed the camera and collimator turrets, while Grundmann designed the prism modules, filter mechanism, Hartmann mask system and the mosaic echelle mounting. The project is scheduled for completion next fiscal year.

C.L Morbey has explored a number of possible optical configurations for the fine error sensor on NASA's Lyman Far Ultraviolet Spectrographic Explorer; as well, he has critically examined issues associated with developing the very stringent baffling required in this telescope and spectrograph.

Data Archiving and Analysis

With the launch of the Hubble Space Telescope, data flow began to the Canadian Astronomy Data Centre (CADC). Two Canadian scientists, both at DAO (Dr. D. Crabtree and P. Stetson), were asked to serve on an international panel to devise mathematical techniques to extract the maximum scientific information from the degraded images of HST. The CADC staff is now concentrating efforts on new programmes aimed at assisting Canadian astronomers to exploit the data from HST and to assist them in preparing proposals for the next cycle of applications.

CAnet began operation; the development of this project, which links computer networks across Canada, was led by Dr. A. Woodsworth of the CADC.

10.3 Dominion Radio Astrophysical Observatory, Herzberg Institute of Astrophysics

Overview

The observatory is located in a valley surrounded by low mountains, about 20 km south-west of Penticton. The site was selected in 1958 because of the protection it provides against man-made emission, and is one of the best sites in North America for radio astronomy at centimetre wavelengths.

DRAO operates two major radio telescopes as national facilities, a (recently upgraded) seven-element aperture-synthesis telescope and a 26-m single reflector telescope. The observatory also operates solar radio telescopes whose data is made available as a service to the scientific and technical community.

The institute employs 29 persons, of whom eight are research scientists. In addition to the 29 full time employees there are approximately five students on-site at any given time, of whom two are graduate students, as well as visiting scientists from time to time. Much of the effort of all staff is devoted to running the facility for outside experimenters from Canadian universities and elsewhere. In the past five years, 87% of projects have involved scientists from outside the DRAO facility. Roughly half the users are based in Canadian universities, and the other half are from outside the country. Recent foreign users have come from the U.S., the U.K., Germany, Holland, Japan, Australia, Russia and Argentina.

The astronomical discipline requires a number of different tools to examine our universe, operating over a range of different frequencies and with varying angular resolutions. Data from different frequencies measuring information from the same location are then commonly studied in parallel to derive an understanding of the many astronomical processes at work. The instruments at the DRAO site have found their greatest use in the study of interstellar matter in our own (Milky Way) galaxy because of their ability to make images of large regions of very faint, extended radio emissions.

The solar radio program has recently been transferred from Ottawa to Penticton, continuing a world acclaimed 40 year series of important basic solar flux measurements and of research into the mechanisms at work in the sun. The solar data is also used for investigations of the Earth's upper atmosphere, and for studies of climatic change. Detection of solar flares provides early warning of disturbances at the Earth which can disrupt radio communications and trigger catastrophic failures in large power distribution networks. Daily

measurements and flare warnings are distributed world-wide by NRC and through the National Institute for Science and Technology in Boulder, Colorado.

Along with the much larger Agriculture Canada Research Station in Summerland, DRAO provides the dominant supply of supply of scientists in the Okanagan area. These two organizations together should be an important resource for the new university. The contribution of this small group to the community is already notable, and includes very substantial hours of donated scientist time both to the the B.C. government "Scientist in the Schools" program, as well as to the hosting of school (and other) visits to the facility. One science teacher from Castlegar, some 200 km distant, annually brings a busload of students (and occasionally a carload of teachers) to visit the laboratory. He has reported that two of his past students separately told him that their visits to DRAO with a class was a catalyst in their decisions to follow careers in science and technology. One went to MIT as an undergraduate. The other went on to graduate studies at a Canadian university.

The laboratory is currently housed in a small permanent building (based on a standard rural police station design!), and a surrounding clutch of trailers. Plans for more appropriate quarters were drawn up in 1990 but have since been shelved. In the longer term, the laboratory is well advanced in planning for a new radio astronomical instrument, a "Radio Schmidt Telescope", which they believe would be a significant world-class instrument, capable of frontier research in many aspects of astrophysics, including studies of our galaxy and of the sun, as well as some important cosmological questions. The projected capital cost of the telescope is about $50 million.

The observatory points proudly to two recent cases of industrial spin-off in B.C. One concerned the development of an economical radio antenna design by Coast Steel of Port Coquitlam, which developed the idea as a result of consultations with DRAO scientists as part of a $25K design contract for the proposed Radio Schmidt Telescope. This work has led directly to at least two contracts in the United States valued at about $1 million, but Coast Steel hope and expect that this is just the start of a substantial new business for them. In the second case, Barrodale Computing of Victoria developed a computer program for converting software from DEC to IBM hardware. This software is now being sold through IBM Canada, and should soon be sold in the U.S. and the U.K. as well. It appears that there are literally thousands of companies with software conversion problems similar to those at DRAO, so that this development could turn out to be quite profitable for Barrodale, and in the meantime has given them useful visibility with IBM in three countries.

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2. **Mandate/Objectives**

The mandate of the Observatory is:

1. To provide forefront radio telescopes for the use of the Canadian and international astronomical communities, and to assist users in obtaining observations with those telescopes or data from them, and
2. To carry on a program of astronomical research and a program of engineering research and development relevant to the present and future telescopes at the Observatory.

3. **Budgetary Information (in thousands of dollars)**

Year	Operating	Salaries Est.	Contracts	Capital	Total
1988/89	$331	$1,440	$89	$185	$1,956
1989/90	$476	$1,440	$101	$300	$2,216
1990/91	$415	$1,320	$119	$225	$1,960
1991/92	$416	$1,680	$53	$540	$2,636

Comments

1. Salaries have been estimated at $60K per person year.
2. The largest item under the heading of contracts is computer service. A new computer system was purchased in 1991. It is still under warranty, and service costs were therefore much smaller in the fiscal year 1991/92.

4. Person years

Year	Research	Technical	Admin	Total
1988/89	7	13	4	24
1989/90	6	14	4	24
1990/91	7	11	4	22
1991/92	7	17	4	28
1992/93	8	17	4	29

Comments

1. The staff numbers shown include permanent and term employees. Casual employees and students are not included. Five students are employed at the facility on a year-round basis, of whom two are graduate students and three are undergraduate (co-op) students.

2. Because the Observatory is a National Facility, the research scientists enumerated in this table are not all spending 100% of their time on their own research. They all have responsibilities for the operation and development of the telescopes, of the computer systems, for assistance to observers who come to use the telescopes, and for other services to the scientific community.

   DRAO report that the current research effort by DRAO staff amounts to about three person-years p.a. The remainder of their time is spent on supporting the research of others by operating the DRAO telescopes, other services to the research community, etc. Some of the time of other staff members, e.g. administrative personnel, goes to support research activities of DRAO scientists, and this is not included. The research infrastructure at DRAO, such as the computer system, is largely dedicated to operation of the telescopes and support of users, and is only partly used for research by local staff.

5.a Principal Criteria for Success

Periodic peer review.

Number and quality of publications which result from use of the facility, both those publications authored by NRC scientists as well as those authored by outside users.

5.b Most Successful Projects

1. The DRAO Synthesis Telescope
2. Scientific research.
3. Student training program.

6.a Patents, Technical Papers and Citations

No patents have been applied for.

Lists of papers published in recent years are provided in some of the descriptive publications listed in 10(a) below.

From 1986-1990 a 59 papers were published leading to a total of 112 citations. A detailed table of citations is filed in the PACST library.

6.b Spin-off Companies

No.

6.c New Products Resulting from Research

Coast Steel Fabricators Ltd. of Port Coquitlam, B.C. have developed a novel concept for an antenna structure as a result of a $25K contract from DRAO related to antenna design for the proposed Radio Schmidt Telescope. Since completing this work, Coast Steel has successfully won two contracts (from Caltech and the Smithsonian) in the U.S. valued at about $1 million. They believe that this is just the beginning for them of a new business building high precision millemetre antenna arrays.

Barrodale Computing Ltd. of Victoria have successfully developed a software program for converting FORTRAN code from DEC to IBM FORTRAN compilers as a result of a successful bid by IBM to provide central computing equipment to DRAO. This software has been marketed since January by IBM Canada on behalf of Barrodale, and it is expected that it will soon be marketed as well by IBM U.S.A. and IBM U.K.

6.d Intangible Benefits

Intangible benefits include:

1. Staff scientists provide lectures in astronomy, e.g. this year four DRAO scientists are participating in a lecture series for undergraduates and staff at Okanagan College.
2. Over 8000 general public and student visitors to the facility in 1991.
3. Involvement of DRAO scientists in the "Scientist in the Schools" program.
4. A number of local newspapers articles and 30 second radio reports on astronomy and science more generally are provided by DRAO scientists. Dr. Landecker of DRAO has been writing a local science column for 14 years.
5. The DRAO library has seen public use, particularly from an Okanagan College professor who plans to pursue a Ph.D. in astronomy.

6.e Outstanding Research Scientists Attracted to B.C.

Approximately half the users of the facility are from outside Canada. Many of them visit the Observatory for periods of one or two months to analyze their observations and to collaborate with DRAO staff. There is currently a scientist from Moscow on a two-month visit to DRAO.

6.f Benefits to Provincial R&D Establishments

1. DRAO expects to play an increasingly important role at Okanagan College as it grows to full university status. DRAO offers college staff research opportunities

and a research infrastructure without any capital expenditure on the part of the college. Opportunities exist for research in astronomy, instrumentation, electronics, and signal and image processing.

2. Graduate student research forms an important part of activity at DRAO, especially in the area of instrumentation. There are currently five undergraduate and two graduate students working at the facility. During the summer there will be six undergraduates and six graduate students at DRAO.

3. A number of university professors participate in the instrumentation development program at DRAO. This includes antennas and electronics, signal processing and image processing, and even some computer science. DRAO's principal collaborators in this work are from the University of Alberta (80%) and UBC (20%).

4. The DRAO site houses a seismograph and other geophysical equipment operated by the Pacific Geosciences Centre, Victoria.

7. Important Collaborative Organizations

1. University of British Columbia.
2. University of Victoria.
3. Okanagan College.
4. Dominion Astrophysical Observatory.

8. Suggestions on Ways B.C. Might Derive Greater Value from the Work at This Establishment

1. DRAO believes that the proposed Radio Schmidt Telescope would be a valuable addition to the scientific infrastructure in the world and would yield industrial spin-offs and a stronger scientific base in B.C., (and particularly in the interior of B.C.).

2. DRAO believes that the effectiveness of Canada's radio astronomy program would be enhanced if the two groups within the National Research Council who are working in this field were both located at DRAO. These groups are (a) the present group of 29 people at DRAO and (b) the group of 19 people in Ottawa who support Canada's participation in the international project, the James Clerk Maxwell Telescope (JCMT). The JCMT is located in Hawaii and the JCMT Group is a part of the Herzberg Institute of Astrophysics (as is DRAO). The two groups have a lot in common scientifically and technically. Uniting them at DRAO would facilitate planning for future Canadian radio telescopes without jeopardizing the dividends from the investments made in present instruments.

9. Industry Overview

The Canadian astronomical research community is estimated (based on an April, 1991 survey) to involve 160 scientists (34 at NRC, 126 in universities), 55 post doctoral fellows, 85 M.Sc. candidates and 104 PhD candidates, to yield a total community of about 400 persons. Of these, about 18% are radio astronomers.

In addition to the radio telescopes at Penticton, the major research facilities open to these researchers include the Canada France Hawaii Telescope and the James Clerk

Maxwell high frequency (sub-millimetre band) radio telescope in Hawaii, in which Canada has a 25% and a 42.5% share respectively, and a variety of optical telescopes including those at the Dominion Astrophysical Observatory in Victoria.

10.a Recent Publications

The following publications were provided by DRAO and are available from PACST:

1. *Dominion Radio Astrophysical Observatory* - Bulletin of the American Astronomical Society, Vol.24-2, p.184, Feb. 1992. This 12-page report covers the period October 1990 to October 1991. It lists staff, and describes involvement in the scientific community, the equipment available, principal scientific projects and graduate student research, and ends with a listing of publications since January, 1990.
2. *Use of DRAO as a National Facility, 1986-1990* - A 17-page internal report dated October 1990 which outlines the research work performed at the facility, showing internal projects, external research work and collaborative research. The procedures for selecting and scheduling observing programs are also outlined, and the membership of the (international) DRAO Observing Priorities Committee listed.
3. *The Dominion Radio Astrophysical Observatory* - A five-page background document prepared for the visit of PACST to DRAO in January 1991.
4. *The Radio Schmidt Telescope - Proceedings of a Workshop held at Penticton, October 11-12, 1989* - A 301-page set of papers given by some of the 70 participants (from eight countries) who attended the workshop.
5. Various short background information papers dealing with the funding of astronomy in Canada, the size of the client communities, statistics on public visits to DRAO, the role of DRAO in the development of high tech industry in B.C.
6. *The Annual Report of the Herzberg Institute of Astrophysics, 1990-91* - A 56-page annual report which includes useful information about DRAO, Penticton (as well as DAO, Victoria).

10.b Key Scientific or Technical Papers

A listing of technical papers published is to be found in several of the documents listed above, notably Nos. 1 and 6.

11. Major Projects

1. Operation of the Synthesis Telescope as a National Facility

Objectives: The provision of a forefront imaging radio telescope as a facility for the Canadian and international astronomical communities. The telescope is a unique tool for research into the properties of the interstellar medium in our own galaxy. DRAO staff make the observations for users, and provide users with preliminary images. Users visit the Observatory to further process these images with the DRAO computer

system, and to interact with the DRAO research staff on the astrophysical interpretation of the data.

Duration: The Synthesis Telescope has been in use as a National Facility since 1981. It is expected to remain a forefront instrument until at least 2007.

Cost: The operation of the Synthesis Telescope requires 20 person years, and operating funds of $300,000 annually.

Significance: The telescope is particularly suited for the study of objects of large angular extent whose emission is very faint. It is a unique instrument for study of the atomic hydrogen gas in interstellar space. The users of the telescope and the staff of DRAO are making pioneering observations of this component of the galaxy.

Links to research in B.C. and elsewhere: The Synthesis Telescope caters to a large community of users. In the five years from 1986 to 1990 44 astronomers made use of the telescope. 87% of the projects involved scientists outside DRAO, although some of these projects were collaborations with DRAO scientists. Of the outside users, roughly half come from Canadian universities and other organizations, and half are drawn from major scientific institutions around the world. B.C. users are from the University of British Columbia, which has a significant group of astronomers.

2. Expansion of the Synthesis Telescope

Objectives: The staff of DRAO is just completing a major expansion of the Synthesis Telescope. The number of antennas has been increased from four to seven. The aims of the expansion are to increase the speed, the sensitivity and the image quality of the telescope.

Duration: 1984 to 1992.

Cost: $1.5 million.

Significance: The increase in speed by a factor of three will allow the telescope to undertake significantly more research projects for the astronomical community. Major surveys of the galactic radio emission are planned, which will generate databases of wide and lasting value to astronomers worldwide. In addition, targeted observations of particular objects will be improved.

Links to research in B.C. and elsewhere: The community of users of the telescope is expected to grow as the power of the enhanced telescope becomes better known.

3. Development and operation of the Solar Radio Monitoring Program

Objectives: This program provides a worldwide community of users with basic data on the sun. The radio flux of the whole sun varies, and it is monitored on a continuous basis using a number of small radio telescopes at DRAO. The daily flux measurement is distributed to the users by electronic mail, by FAX, and is broadcast in conjunction with the time signals by the National Oceanic and Atmospheric Administration in Colorado. The radio telescopes can also detect solar flares and other solar activity which can have a major impact on terrestrial events.

Duration: 1946 into the future. This program is the successor to one which began near Ottawa in 1946, and an unbroken series of precise measurements has been maintained since then. It is one of the longest series of fundamental data on the sun ever obtained. A telescope for this work has been located at DRAO since 1964. In 1990 the entire program was transferred to DRAO; a telescope was moved to DRAO from Algonquin Park in Ontario and a staff of three was transferred from Ottawa.

Cost: $35,000 per annum, plus 3 person-years. It is significant that the U.S. Government spends $50,000 each year to distribute the data -- more than the Canadian Government spends to obtain it.

Significance: The Penticton 2800 MHz Solar Flux has become one of the fundamental measures of solar activity. It has both scientific and commercial application.

Commercial users of the data include electric power companies and authorities, and companies engaged in geophysical mapping and exploration. Solar flares (explosive events on the Sun) interact strongly with the terrestrial environment. They can cause aurora and geomagnetic storms. The DRAO program issues warnings of geomagnetic disturbances to power companies and the geophysical community. Geomagnetic storms can disrupt magnetic exploration for minerals and oil, and can trigger instabilities in large power networks. Such an event caused a 9-hour outage of almost all of Quebec Hydro on March 13, 1989. Other uses of the Solar Flux values include predictions of terrestrial radio propagation and estimates of upper atmosphere drag on satellites (commercial and other).

Links to research in B.C. and elsewhere: The Penticton Solar Flux is used by scientists in many countries in an amazing variety of investigations. As the standard indicator of solar activity, it is widely used in solar physics research. It has recently gained new significance through its application to studies of climatic change because the series of measurements of the solar radio output gives an indication of the inherent stability of the radiation output of the sun, that is to say an indication of the energy input to the earth's climate system.

4. Operation of the 26-metre Radio Telescope

Objectives: The 26-m Telescope is used to supplement observations made with the DRAO Synthesis Telescope, and is also used for independent research programs.

Duration: The 26-m Telescope was the Observatory's first instrument. It came into operation in 1960, and will be used into the foreseeable future.

Cost: $20,000 per annum and one person year.

Significance: The telescope is available for observing projects of very long duration and is exploited for this reason. Examples include the study of OH molecules in Halley's Comet (10 months of observations), long-term studies of variability of some sources, and observations where very long integration times are necessary (sometimes 24 hours on a single point). The telescope is also used to provide complementary data for every field observed with the DRAO Synthesis Telescope.

Links to Research in B.C. and Elsewhere: All users of the Synthesis Telescope use 26-m data as well. Users of the 26-m Telescope as a stand-alone instrument come mainly from Canadian universities. Okanagan College plans to incorporate observations with the 26-m Telescope into a course in Astronomy to be offered to students in 1992.

5. Survey of the Galactic Plane

Objectives: This survey will use the DRAO Synthesis Telescope to observe a large part of the Galaxy in which we live. The resulting data will be made available to the entire astronomical community as a computer-readable database.

Duration: 1988 to 1996

Cost: Initially, no cost beyond the operation of the telescope. As the survey progresses, requests for funding of positions at universities will be made to the Natural Sciences and Engineering Research Council.

Significance: Astrophysical research is moving increasingly in the direction of comparative astronomy, where data from many wavebands is consulted in order to study one object or one class of objects. This type of research is becoming easier as computers advance in their ability to consult extensive databases rapidly.

The database which results from this survey will be unique because of the telescope's ability to map the atomic hydrogen component of the interstellar gas. The database generated from this survey will be of great value to astronomical research worldwide. It will complement similar databases obtained from other telescopes, both ground based and satellite borne.

Links to research in B.C. and elsewhere: Part of this survey work has already been carried out. It was initiated by DRAO scientists, but university scientists and their graduate students have joined in.

A consortium of university researchers is currently being established to expand the scope of the survey. Resources for additional personnel will be sought from the Natural Sciences and Engineering Research Council.

6. Development and construction of the RadioAstron correlator

Objectives: Canada is a partner in an international project to place a radio telescope into Earth orbit and to use it in conjunction with terrestrial telescopes to form an imaging telescope. The project was initiated by scientists from the former Soviet Union, where the launch vehicle, the satellite, and the orbiting antenna are being built. The partner countries are Canada, the United States, Australia, Finland, and Europe. The scientific and technical leadership for Canada's contribution is being provided by a DRAO scientist.

Canada's contribution is funded through the Canadian Space Agency. A digital signal processing system (a correlator) is being designed and built at DRAO for this project. Canada's other contribution is a data recording system now being built at York University.

Duration: Design began in 1991. Present plans call for delivery of two completed correlators in 1995. Canadian scientific participation will begin after the launch (in 1996) and is expected to continue for at least four years.

Cost: For the DRAO portion of the project $2.5 million is allocated over four years, including salaries for a staff of four for that time.

Significance: RadioAstron will be the first telescope array to use an antenna in space. There is little doubt that this is the first step into space for radio astronomy, and further arrays will be built, perhaps with many antennas in space. The effective dimension of the RadioAstron array will be 70,000 km, the size of the satellite orbit, but such telescope arrays may eventually span sizes as large as the Earth's orbit around the Sun, a diameter of 300-million km. Partnership in the RadioAstron project will give Canadian astronomers a foothold in this new area of research.

Links to research in B.C. and elsewhere: The Canadian Space Agency has funded the design effort through a contract to the University of Victoria (handled through the Electrical Engineering Department). Four people working at DRAO are employees of the University. The Electrical Engineering Department is also providing expert advice on the development of new semiconductor circuits for the project.

7. Scientific Research

Objectives: Scientific research at DRAO is focussed into a number of areas closely related to the telescopes at the Observatory. The research is mostly concerned with the interstellar medium, with a smaller effort in the area of solar physics. The research effort involves the use of telescopes at DRAO and at other observatories, and a large measure of collaboration with Canadian and other astronomers.

Duration: Continuing.

Cost: The annual effort devoted to scientific research is approximately three person years. Expenditures on research are $50,000 annually, mostly on travel and publication expenses. Annual library expenditures are $45,000 of which about $15,000 is used for research purposes.

Significance: DRAO scientists are in leadership roles in Canada in a number of research areas. This is as it should be: it is impossible to run a first-class scientific facility without first-class scientists.

Links to research in B.C. and elsewhere: Research collaborations exist between DRAO scientists and scientists in Canada and in many other countries.

8. Engineering Research and Development

Objectives: A world-class radio telescope requires continual development if it is to remain at the research forefront. DRAO staff participate in engineering research relevant to many areas of radio astronomy instrumentation: antennas, low-noise receivers, radio-frequency and digital signal processing techniques, and image processing techniques. This research results in publications, which appear in the

engineering literature. Much of this research involves graduate students, and therefore has a training aspect.

Duration: Ongoing.

Cost: About 2 person years are devoted to this work. Much of it is done by graduate students, whose numbers fluctuate. The resources required for their work are small, of the order of $10,000 annually.

Significance: Radio astronomy cannot survive as a vital scientific discipline without a backbone of technical skill and instrumentation development. A considerable fraction of the Canadian supply of skill in this area lies with the staff of DRAO and their university collaborators.

This research is relevant the development of the DRAO telescopes, and to the development of new radio telescope for Canada. It is also of interest to radio telescope designers in other countries.

IT IS IN THIS AREA THAT MOST OF THE "SPIN-OFF" BENEFITS FROM RADIO ASTRONOMY ARE GENERATED. Since radio astronomy techniques are closely allied to the techniques of communications and other practical pursuits, many developments at DRAO, and at other radio astronomy establishments, are of vital importance to the progress of technology. Radio astronomers continue to lead the world in many technical disciplines.

Links to research in B.C. and elsewhere: DRAO staff have a long standing collaboration with the Electrical Engineering Department at the University of Alberta in this area. Graduate student projects have also been undertaken with the Electrical Engineering Department at the University of B.C.

9. Student Training

Objectives: DRAO provides a range of opportunities for training of students from Canadian universities and colleges in high-technology disciplines, physics, computer science, and electronic engineering. Currently, there are typically five students at DRAO at any time. Their stay at DRAO is usually four months (one university semester or one summer). Many of these students are in Co-operative Education programs.

In addition, through collaboration with various universities, a number of graduate students are at DRAO carrying out significant fractions of their thesis research. These students are pursuing Masters or Doctorates in Astronomy and in Engineering. Three DRAO scientists hold Adjunct Professor appointments at Canadian universities in order to be able to supervise graduate student research.

Duration: Students have been an integral part of DRAO since its opening in 1960, and will continue to be.

Cost: The cost of approximately five positions for undergraduates or students of technology are borne from a central NRC fund. Stipends for about three graduate students are derived from the Natural Sciences and Engineering Research Council through collaborating university professors. The annual contribution (which is outside the DRAO budget) is therefore about $140,000.

Significance: Universities are increasingly limited in their ability to provide practical experience in their courses because of the high cost of laboratory equipment and facilities. Co-operative programs are part of the answer. Experience at DRAO provides students with contact with modern equipment and facilities, and offers experience in tackling real-world problems which are impossible to present in a three-hour laboratory class.

Students who have graduated with higher degrees in engineering after working at DRAO have readily found positions in industry in B.C., Alberta and Ontario.

Some students who have gained experience in astronomy at DRAO at either the undergraduate or the graduate level remain in astronomy and go on to become research scientists. In this way DRAO is an essential ingredient in maintaining the viability of Canadian astronomy.

Links to research in B.C. and elsewhere: The graduate student program at DRAO has drawn students from the Universities of British Columbia, Victoria, Calgary, Alberta, and Toronto.

10. The Radio Schmidt Telescope

Objectives: The DRAO staff is currently preparing a proposal for an innovative and unique radio astronomy facility which has attracted considerable interest within the Canadian astronomical community and internationally. It would consist of 100 antennas of diameter 12m in an array about 2 km in extent. The telescope would be built on the DRAO site.

The concept of the Radio Schmidt Telescope is a natural outgrowth of the experience of the DRAO staff.

Duration: The design and construction of such a telescope would require ten years after approval. Its useful scientific lifetime is hard to estimate, but would probably be at least 30 years.

Cost: The detailed proposal for the Radio Schmidt Telescope has not yet been completed, so that the resources necessary to build and operate the facility and the time scale of the project are somewhat uncertain. Nevertheless, the preliminary cost targets foresee a capital cost of $50 million (1990 dollars). The telescope would require a staff of about 60 to operate it as an effective national facility, giving an estimated annual operating cost of $5.0 million. Funding for some design studies has been provided by NRC.

Significance: This telescope will be an extremely powerful instrument and will, without doubt, provide answers to many outstanding questions in astrophysics. Its data will very probably revolutionize several areas of astronomical research. It will be a very versatile telescope and so will have many uses and will attract astronomers from around the world.

The construction of a telescope of the type described above has only recently become possible through advances in technology. In particular, the advent of very sensitive but simple microwave amplifiers, of optical fibre transmission lines capable of carrying data

at high speeds, and the increasing power of digital and computer technology are the keys to this new type of radio telescope. The technology involved is closely related to industries in which Canada is strong, in particular the communications industry and the computer systems and signal processing industry; the design and construction of this telescope could have substantial spin-off benefits for Canada.

In fact, the telescope could be largely built by industries already operating in British Columbia. Its design and construction would provide those industries with challenges which could be translated rapidly into internationally marketable skills and products.

If the Radio Schmidt Telescope were built, it would be the only major Canadian astronomical facility on Canadian soil. All other Canadian astronomical facilities will be outside Canada. This makes a big difference to the economic impact of such a project.

Links to research in B.C. and elsewhere: It is generally recognized that international collaboration would be desirable for this project. A workshop held in Penticton in October 1989 to discuss the proposal was attended by 70 scientists and engineers from eight countries. Interest has been expressed in the project by groups of scientists in Germany, in France, and in the United States.

10.4 Engineering Research Groups in Vancouver

Overview

NRC currently has two engineering research groups in Vancouver, each associated with a larger Engineering Institute based in Ottawa. The two groups combined comprise 28 full time employees and consume an NRC budget of approximately $2.3 million plus about $225 thousand in outside contracts. In conjunction with a comprehensive review of engineering R&D needs in Canada and NRC's role in addressing those needs, the Council is now considering establishing a new institute in Vancouver which has been given the working title of Institute for Machinery Research (IMR). If established (in 1993?), IMR would incorporate the current NRC resources in Vancouver, together with new staff and facilities to fulfill its mission.

The proposed mission of the new Institute is[2]:

> To improve Canada's productivity, competitiveness, environmental and social well-being by undertaking, supporting, and promoting research, development and the application of advanced technologies to the design, development, operation and maintenance of industrial machinery systems, especially those for the Canadian resource, transportation and manufacturing industries.

The research at the institute as currently envisaged (but subject to the results of an extensive outside consultation process with industry, governments, and academia (yet to get under way), could comprise the following programs:

1. *Machine Dynamics* (Rotor Dynamics, Machine Vibrations, Acoustics and Noise Control, Motion and Energy Flow)

2. *Machinery Control Systems* (Non-linear Controls, Computation for Control, Sensor and Actuator Development, Optimization of Interconnected Controllers)

3. *Tribology* (Rolling Contact Tribology, Sliding/Impacting Contact Tribology, Surface Engineering, Lubrication Technology)

4. *Machine Synthesis* (Conceptual Design, Design Simulation and Optimization, Mechatronic Design)

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[2]The proposed mission and program are taken from a draft proposal for the N.R.C. Institute for Machinery Research dated January 23, 1992.

5. *Machinery Condition Monitoring and Diagnostics* (Vibratory and Acoustic Analysis, Wear Debris Analysis, Instantaneous Crankshaft Angular Velocity Technology)

It is proposed that the Institute be initiated by the amalgamation of certain existing resources from the Tribology and Mechanics Group in Vancouver, the Vibrations, Acoustics and Machinery Diagnostics Group in Ottawa, the Systems Group in Vancouver and the CIIT Group in Winnipeg. These groups would provide an aggregate of 65 person years including some 30 current vacancies. Reallocations in subsequent years would see the staff complement grow to 95 N.R.C. employees (20% on term appointments), and there would be an additional 40 research associates, collaborators and guest workers for a total complement of approximately 135 persons. These researchers would be accommodated in the ex-Forintek Building now taken over by NRC.

It is anticipated that the total budget for the new Institute would be about $8.9 million p.a., of which $7.7 million would be provided by N.R.C., the remainder comprising revenue from outside (primarily industry) sources.

It is planned that IMR would be a national research institute serving all Canadian designers, builders, operators and maintainers of industrial machinery. A vital objective of the Institute would be to develop and maintain strong associations with Canadian (and especially B.C.) industry. Without such strong links, it would be difficult if not impossible for the Institute to accomplish its mission.

An important factor in NRC's eventual decision as to whether or not to proceed with the institute will be the degree of enthusiasm and support shown by British Columbians, and especially by B.C. industry.

The two engineering groups currently operating in Vancouver are the Tribology Mechanics section of the Institute of Mechanical Engineering, and the Systems Laboratory of the Institute of Information Technology. The former of these has been in existence since 1972 and comprises 18 persons of whom six are research scientists. Its focus is on applied studies in tribology (friction) and mechanics aimed at solving major generic and some specific problems faced by Canadian industry. Perhaps its greatest research success has been its work on rail wear, which is estimated to save the Canadian railways approximately $100 million p.a. Other projects include studies of braking problems on the

Canadarm (in space), the development of a log yarding system, and a variety of other theoretical and practical friction studies.

The Systems Laboratory of the Division of Mechanical Engineering was created in 1987 with the objective of focusing on information technology of relevance to the resource and transportation industries. The Systems Laboratory joined the new Institute for Information Technology in 1990 as part of a larger NRC restructuring. The Laboratory remained in Vancouver but broadened its focus somewhat beyond the resource and transportation sectors. The research focus is on "Symbiotic systems" software and object oriented programming. Nearly all research projects are collaborative, and client application oriented, with a small amount of supporting development. Projects with resource and transportation sector clients as well as a variety of other industries have been successfully completed, and a number of resulting software products have been commercially licensed for royalties. The group currently comprises 10 persons, of whom four are research scientists.

1. Address

Tribology and Mechanics Laboratory:
3650 Wesbrook Crescent, Vancouver, V6S 2L2

Systems Laboratory of the Institute of Information Technology:
6620 NW Marine Drive, Vancouver, V6T 1Z4

Contact

Tribology and Mechanics Group: Dr. Clive Dayson

Tel: (604) 666-2623 Fax: 666-7203

Systems Laboratory: Mr. Dilip Kotak

Tel: (604) 666-1051 Fax: 666-4449

2. Mandate/Objectives

The mandate of the *Tribology and Mechanics Laboratory* is to undertake applied studies in tribology and mechanics aimed at solving major generic and other specific problems faced by Canadian industries in these technical areas.

The mandate of the *Systems Laboratory of the Institute of Information Technology* is:

The Systems Laboratory focuses on applying software technology to decision support systems for planning, scheduling, monitoring, and control of industrial operations. These types of systems are usually large and complex and require integration of such

software technologies as databases, GIS systems, expert systems, and real time control systems.

3. Budget (in $000)

1. The budget of the *Tribology and Mechanics Laboratory* is as follows:

Outside Revenues (in $000)

Year	Operating	Salaries	Capital	NRC TOTAL	Contracts	In Kind
1988/89	190	1020	50	1260	80	0
1989/90	185	960	128	1273	151	0
1990/91	204	1020	138	1362	211	144
1991/92	195	1080	50	1325	200	170
1992/93	200	1080	100	1380	150	150

Comments

a. Work contracted out to industry or elsewhere is negligible.

b. Salary costs have been obtained by multiplying total person years by an average $60K p.a. cost (including benefits). This number has not been adjusted for inflation.

c. In 1991/92 contracts were received from the following companies: International Hard Suits, Esso Resources, Domtar Inc., General Motors Canada Ltd., Vancouver Skytrain, Century Oil, CP Rail, Westinghouse Canada Ltd., Hawker Sidley.

d. In 1991/92 collaborative research programs were carried out with Alcan, SFU Energy Research Institute, Univ. of Cambridge, Quebec Cartier Mining Railway, Esso Resources, Domtar Inc., Ramsay Machine Works, Ottawa University, Korea Standards Research Institute, Kingsburg Inc., General Electric Canada Inc.

2. The budget of the *Systems Laboratory* was not provided in detail, but can be reconstructed as follows:

a. The budget was growing gradually in the interval from its founding in 1987 to 1990/91 when it attained a roughly stable state at roughly $850 K p.a. This total is calculated as follows:

Salaries (10 py)	$600 K
O & M	$150 K
Capital	$150 K
TOTAL NRC FUNDING	$900 K
Outside funding	$75 K

b. Revenues were spent on external contracts for software R&D to local B.C. companies, and on collaborative projects with clients. Capital expenditures were primarily for computer hardware and software.

4. Person Years

The *Tribology and Mechanics Laboratory* has the following distribution of employees:

Year	Research Scientists	Scientific Support	Admin.	Total
1988/89	5	9	3	17
1989/90	5	9	2	16
1990/91	6	9	2	17
1991/92	6	10	2	18
1992/93	6	10	2	18

Comments

During the year 1991 there was one additional scientist on staff paid for out of contract revenue. In addition, at any given time there are about four guest workers on site, including co-op and summer students.

The *Systems Laboratory of the Institute of Information Technology* employs ten persons, of whom 4 are research scientists, 5 are technical specialists and one has an administrative role. An additional person year is devoted to co-op or summer students.

5.a Principal Criteria for Success

The *Tribology and Mechanics Laboratory* has the ability to solve medium to long term industrial problems, hence our ability to attract research contracts and collaborative research partners from industry and academia.

The *Systems Laboratory of the Institute of Information Technology* uses successful technology transfer of laboratory developments to industry as its principal criterion of success.

5.b Most Successful Projects

For the *Tribology and Mechanics Laboratory*:

1. The development of the preventative rail grinding method of rail maintenance, which is now saving B.C. Rail about $8 million p.a. and Canadian railroads generally about $100 million p.a.
2. Diagnosis of a major problem in the Canadarm braking system, and the development of new, more effective materials for that application.

For the *Systems Laboratory of the Institute of Information Technology*:

1. The development of symbiotic software for airport (flight) capacity planning. This software won first prize for the practice of operations research at the 1991 meeting of the Canadian Operational Research Society. The software (called AIRSYM) has recently been licensed to Aviation Research Corporation of Montreal. Forecast sales are unknown.

2. The group developed important enhancements to a new object oriented software language named *Audition*. This software has now been licensed to King Matkowski and Associates of Vancouver. Forecast sales are unknown.

6.a Patents, Technical Papers and Citations

Patents have been applied for on a rail-wheel lubricant and on the skyline yarding system.

The *Tribology and Mechanics Laboratory* supplied a partial list of publications which is stored in the PACST library.

The *Systems Laboratory of the Institute of Information Technology* has also supplied a partial list of publications which is stored in the PACST library.

Neither group keeps records of citations.

6.b Spin-off Companies

No.

6.c New Products Resulting from Research

Lighthouse Industries of B.C. commercialized a wheel lubricant for mass transit systems. This company was subsequently acquired by Century Oils (U.K.). The oil is still produced in B.C. and is thought to involve annual sales of about $24 million, and to result in employment for about 12 persons.

Aviation Research corporation in Montreal, employing 6 people, uses and markets AIRSYM internationally, under license from NRC, for airport planning and design. They are also collaborating with NRC in the development of several additional software products, using the same technology, to create and market a complete family of airport planning and management tools.

King Mankowski and Associates, which employs four people, was recently formed. The *Audition* software, important enhancements of which are licensed from NRC, is a key product of this new company.

6.d Intangible Benefits

Very substantial noise reduction on the Vancouver Skytrain (and reduced rail wear) as a result of research on wheel-rail interaction. Also $8M p.a. rail maintenance savings by BC Rail.

No major intangible benefits have yet surfaced to the knowledge of the *Systems Laboratory of the Institute of Information Technology*, however the "symbiotic systems"

approach to software has been defined by NRC and is gaining acceptance amongst software developers in B.C. and elsewhere.

6.e Outstanding Research Scientists Attracted to B.C.

Dr. Dmochowski of the Polish Academy of Sciences was attracted to the Tribology Laboratory because of the journal bearing research program.

6.f Benefits to Provincial R&D Establishments

Five research officers of the *Tribology* group teach Mechanical Engineering courses at U.B.C. and participate in graduate student training. There is also a co-operative research program underway with SFU related to the study of defoliated graphite.

The *Systems Laboratory* scientists have taught an Operations Research course at U.B.C., and maintain collaborations with faculty at U.B.C., SFU, UVic and with BCIT's ARCS laboratory. The group has consistently employed one maintains one university co-op student on site since 1987.

Two *Systems Laboratory* scientists have given numerous invited lectures at several B.C. universities and colleges.

7. Important Collaborative Organizations

Collaboration with BC Rail on preventative rail grinding field trials, and with the University of Cambridge and B.C. Transit on research into the mechanisms of short pitch rail corrugation in rapid transit systems are important to the *Tribology* laboratory. The National Tribology Centre at Risley in the U.K. is a larger and somewhat more applied role model.

The Transport Development Centre in Montreal has been an important collaborator on several *Systems Laboratory* projects.

8. Suggestions on Ways B.C. Might Derive Greater Value from the Work at This Establishment

Assist in the establishment of the proposed new Institute for Machinery Research.

The Systems Laboratory would like to see more collaboration amongst resource industry research organizations.

9. Industry Overview

The *Tribology and Mechanics Laboratory* works for a spectrum of Canadian industries from most sectors and from across the country. The main area of specialization to date has been tribology, an area in which the potential saving due to reduced friction and wear have been estimated at $1 billion p.a. for Canada. (Associated Committee Report NRCC 26556, 1986)

The *Systems Laboratory* is endeavouring to focus, although not exclusively, on the resource and transportation sectors of the economy. These two sectors account for $88[3] billion and $25 billion of sales annually in Canada respectively.

10.a Recent Publications

The following material has been provided and is stored in the PACST library:

1. Several two or four page "Fact Sheets" variously titled *The National Research Council, NRC Institute for Mechanical Engineering, Tribology and Mechanics Laboratory, Mechanical Engineering Highlights.*
2. A series of nine two to four page information sheets concerning the activities of the *Systems Laboratory*, two of which give overview information, and the remainder of which describe specific projects.

10.b Key Scientific or Technical Papers

The *Systems Laboratory* supplied the following papers which are filed in the PACST library:

1. *Airport Capacity Planning Symbiotic System (AIRSYM): Combining Human and Artificial Intelligence* - A 20 page paper by M. Scriabin, J. Farlette, D. Kotak and M. Mathews which won first prize at the CORS Competition on the Practice of O.R. at Quebec, May 21-23, 1991.
2. *Wood Production Planning and Inventory Control System* - A 16 page paper by A.J. MacDonald, Dilip Kotak and Ken Whale delivered at the GIS'90 Symposium in Vancouver, March, 1990.
3. *Decision Support Systems in Forestry: The Management of Complexity* - A six page paper by D. Kotak, K. Jones and K. Whale which appeared in the October, 1990 edition of *Canadian Forest Industries.*

Various lists of publications have been supplied as identified in the response to question 6a.

11. Major Projects

The *Tribology and Mechanics Laboratory* listed the following projects:

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[3]These statistics are drawn from several sources. The resource industry gross revenues are for 1985-86 and are drawn from Statistics Canada cat. 15-001 (*Gross Domestic Product by Industry*). The transportation gross revenue is the sum of gross revenues from four special Statistics Canada publications respectively on Rail, Aviation, Trucking and Shipping. All refer to data in the 1985 to 1989 time period. Note that the private automobile industry is not included in the statistics, and, given the time span over which the statistics were collected, they should be treated as order of magnitude only.

1. **Short Pitch Wheel/Rail Corrugation Study**

This important study consumed eight person years over the 1986-1991 time frame and resulted in the complete elimination of wear corrugations and associated noise pollution through the development of a high positive friction lubricant and a method to control the shape of the rail-wheel profiles.

Six months after opening, 80% of the track and many wheels on the Vancouver Skytrain were corrugated. Noise, reaching levels of 100 to 110 dBs, was unbearable to passengers and residents alike. A detailed study of contact conditions indentified close conformity between worn wheel and rail profiles, and frictionally induced (stick-slip) vibrations as the major cause of noise and corrugatory wear. Theoretical modelling led to the development of new wheel and rail profiles, which eliminated the close conformity. Lab testing of various friction reducing compounds led to the development of HPF modifier, and the elimination of stick-slip. The Skytrain is now quiet, and the concepts and solutions developed in co-operation with Skytrain and the University of Cambridge are now being applied on many other mass transit systems around the world.

2. **Wear and Contact Fatigue Study for Railway Rail**

This study consumed about 12 person years p.a. over the six year period 1982-1988. The replacement of worn and spalled rails represents a major capital expenditure to every railroad. The comprehensive theoretical and experimental study of this problem led to the development of new rail surface maintenance methods and improvements in wear resistance of rail steels. New maintenance methods consist of controlled lubrication and grinding procedures known as preventative grinding. New geometries of ground rail profiles together with specific grinding intervals were developed and validated by field tests. This new preventative maintenance method results in a threefold increase in rail life. Annual savings to B.C. Rail are estimated at $8 million p.a., and to Canadian railways generally at about $100 million p.a. The methodology has now spread to the U.S., Mexico, Brazil and Australia.

The research was carried out in co-operation with Dr. D. N. Fevgredo (EMR, Ottawa), Prof. H. Ghonem (Univ. of Rhode Island) and Prof. K. L. Johnson (Cambridge University).

3. **Tribology of Space Mechanism Brake Materials**

This was a two year project involving two persons. Funding included $60 K per annum from outside sources.

The goal was to find brake lining materials suitable for extended use in a low earth orbital environment.

The materials identified provide high friction and low wear in vacuum, and are important to extending the life of remote manipulator systems in space. The prime Canadian contact for this research is Spar Aerospace.

4. **Skyline Yarding System for Selective Log Yarding**

This project has thusfar consumed five person years over an eight year time frame. The objective is to develop a low cost and effective harvesting device suitable for selective logging. The device is patented and undergoing field trials. If the field trials are

successful. Ramsay Machine Works of Victoria will manufacture and sell the device under license.

5. **Theoretical Modelling of Journal Bearing Performance**

This is a continuing project with a ten year time frame, and consumes one person year p.a. The objective is to provide improved models for predicting steady state and dynamic performance of tilting pad journal bearings, leading particularly to improved design and maintenance procedures for journal bearings in heavy machinery used by utilities and others. Ontario Hydro has been the main client of this project.

6. **Vibration Problems in Steam Turbines**

This was a short (two week) project in 1991 during which a severe vibration problem in a steam turbine located in a MacMillan Bloedel mill in Port Alberni was resolved, allowing the paper machine to be speeded up by 7%, for an estimated value to the company of $2 million p.a.

7. **Frictional Characteristics between Paper and the Surface of Steel Rolls**

A two year project involving one person year total under contract and in collaboration with Domtar.

The particular technical problem which triggered the activity arose when the papermaking system was converted from an acidic to an alkiline process. The resulting change in the friction between the paper and the steel rollers over which it fed led to severe production problems in the manufacture of folded continuous feed papers. This problem was solved, and has since led to ongoing collaborative work with Domtar.

8. **Evaluation of Wear Resistant Materials for Downhole Components in Heavy Oil Production**

This four-year program has consumed approximately 0.5 person years p.a. and has attracted over $100K in contracts and collaborative contributions from Esso Resources Canada Ltd. The introduction of multiple deviated and slant oil wells all pumped from one pad has led to a sharp increase in wear-related failures. The research program has helped to identify the wear mechanisms involved, and several materials with superior wear properties in this environment have been identified.

The *Systems Laboratory of the Institute of Information Technology* listed the following projects, none of which have yet reached a stage where their market impact can be readily evaluated:

1. **Participation in SNC's *Projert* Project**

The *Projert* project is a $30 million, five-year project led by SNC of Montreal aimed at providing a land management data base capable of fusing inputs from remote sensing satellites, aerial photographs and land based surveys. Forest management is expected to be an important application of this system. NRC is contracted to provide two person years per annum towards this project, providing expertise in object oriented technology and symbiotic systems.

2. **Airport Planning Software**

Development of a planning and modelling tool for ground and terminal aspects of airport planning (to complement the *Airsym* program referred to in the response to question 4). This project commenced late in 1991 and is scheduled for completion late in 1993. It involves two NRC experts full time. It is expected that the resulting software will be licensed to the Aviation Research Corporation of Montreal.

3. **Employee Scheduling System for Hospitals**

A nurse scheduling system for hospital use, originally developed at BCIT, has moved with its developer to NRC. The software is virtually complete and has been licensed. Fifteen copies have been presold. It is currently requiring about 0.5 person years of scientist time.

4. **Object Oriented Language Development**

Work on the *Audition* object-oriented language is continuing at a low level (1 py), as a part of the license agreement with King Matkowski and Associates of Vancouver.

5. Forest Crew and Equipment Scheduling Software

Software for the short term scheduling of crews and equipment in forest harvest planning and for long term harvest site selection has been developed by the Laboratory via several collaborative projects with forest companies in B.C. and elsewhere. The software has been licenced for commercialization on an interim basis. Although developed for the forest industry, it is quite generic and is suitable for short and long term scheduling in other industries. Licence negotiations are underway with the mining industry to adapt it to open-pit and underground mine management.

APPENDIX 1

FEDERAL INTRAMURAL RESEARCH FACILITIES IN B.C.

Listed below are the current addresses (as of April, 1992) of Federal Government research facilities in B.C., along with the names and titles of people contacted.

1. AGRICULTURE CANADA

Agassiz Research Station

P.O. Box 1000
Agassiz, B.C., V0M 1A0

Dr. J.M. Molnar, Director

Tel: (604)796-2221 Fax: Same as phone number.

Kamloops Research Station

3015 Ord Road
Kamloops, B.C., V2B 8A9

Dr. Klaas Broersma, Director

Tel: (604)376-5565 Fax: 376-73341

Prince George Experimental Farm

R.R. #8, R.M.D. #6,
Prince George, B.C., V2N 2H8

Tel: (604)963-9632

Summerland Research Station

Agriculture Canada Research Station
Summerland, B.C., V0H 1Z0

Dr. John Dueck, Director
Dr. Norman E. Looney, Head, Pomology and Viticulture Section

Tel: (604) 494-7711 Fax: 494-0755

Vancouver Research Station

6660 N.W. Marine Drive
Vancouver, B.C., V6T 1X2

Dr. Dean L. Struble, Director

Tel: (604) 224-4355 Fax: 666-4994

2. ENERGY, MINES AND RESOURCES CANADA

Pacific Geoscience Centre, Geological Survey Of Canada

P.O. Box 6000, Sidney, B.C. V8L 4B2

Dr. Mel Best, Director

Tel. (604) 363-6500 Fax: 363-6739

Cordilleran Division, Geological Survey Of Canada

4th Floor, 100 West Pender Street
Vancouver, B.C., V6B 1R8,

Dr. D. Tempelman-Kluit, Director

Tel: (604) 666-0529 Fax: 666-1124

3. ENVIRONMENT CANADA

Atmospheric Environment Services, Pacific Region

700 - 1200 West 73rd Avenue, Vancouver, V6P 6H9

Mr. Kirk Johnstone, Director, Atmospheric Issues and Services
Mr. Mert Horita, Chief, Techniques, Technology and Training (664-9070)

Tel: (604) 664-9120 Fax: 664-9195

Environmental Protection: Vancouver

224 West Esplanade, North Vancouver, V7M 3H7

Dr. Brian Wilson, Regional Director
Mr. Fred Claggett, Policy Adviser (666-6262)
Mr. Andrew Fabro, Labrarian (666-5914)

Tel: (604) 666-0064 Fax: 666-7463

Inland Waters Directorate, Pacific And Yukon Region

1001 West Pender Street, Vancouver, V6E 2M9

Dr. Vic Niemela, Regional Director
Ms. Karen Hurley, Environmental Planner

Tel: (604) 666-3357 Fax: 666-6756

(Contacted, but not interviewed as they do no research)

Canadian Wildlife Service, Pacific And Yukon Region

P.O. Box 340, Delta, V4K 3Y3

Dr. Art Martell, Regional Director
Dr. Steve Wetmore, Chief, Ecosystems Evaluation and Research

Tel: (604) 946-8546/666-0143 Fax: 946-7022

4. FISHERIES AND OCEANS CANADA

Institute Of Ocean Sciences

9860 West Saanich Road, Sidney, V8L 4B2

Dr. John C. Davis, Director for Science, Pacific Region
Mr. Terry Curran, Industrial Liaison Officer & Chief, Engineering Services

Tel: (604) 356-6514/6515 Fax: 363-6479

Vancouver Office: 555 West Hastings St.

Tel: 666-8169 Fax: 666-6089

Pacific Biological Station

Hammond Bay Road, Nanaimo, V9R 5K6

Dr. R. J. Beamish, Director

Tel: (604) 756-7041/7040 Fax: 756-7053

West Vancouver Laboratory

Marine Drive, West Vancouver, V7V 1N6

(included with the Pacific Biological Station, and under its direction)

Tel: (604) 756-7041/7040 Fax: 756-7053

5. FORESTRY CANADA

Pacific Forestry Centre

506 West Burnside Road, Victoria, V8Z 1M5

Dr. T. John Drew, Director General
Mr. Kerry C. Deschamps, Technology Transfer Forester (363-0691)

Tel: (604) 363-0600 Fax: 363-0775

6. NATIONAL DEFENCE

Defence Research Establishment, Pacific

FMO Victoria, Victoria, V0S 1B0

Dr. Todd Garrett, Chief of the Establishment
Mr. S.E. Forshaw, Head, Plans and Programs (363-2868)

Tel: (604) 363-2867 Fax: 363-2856

7. NATIONAL RESEARCH COUNCIL OF CANADA

Institute of Mechanical Engineering, Tribology Mechanics

3650 Wesbrook Crescent, V6S 2L2

Mr. Clive Dayson
Tel: (604) 666-2623 Fax: 666-7203

Institute of Information Technology, Systems Laboratory

6620 NW Marine Drive, V6T 1Z4

Mr. Dilip Kotak

Tel: 666-1051 Fax: 666-4449

Dominion Astrophysical Observatory, Herzberg Institute of Astrophysics

5071 West Saanich Road, Victoria, V8X 4M6

Dr. James E. Hesser, Director

Tel: (604) 363-0007 Fax: 363-0045

Dominion Radio Astrophysical Observatory, Herzberg Institute Of Astrophysics

P.O. Box 248, Penticton, V2A 6K4

Dr. L. A. Higgs, Director
Dr. Tom Landecker

Tel: (604) 493-2277 Fax: 493-7767

APPENDIX 2

QUESTIONS SENT TO HEADS

OF FEDERAL RESEARCH FACILITIES IN B.C.

The head of each facility was contacted by telephone during the months of February and March, 1992, and arrangements were made for a meeting. Once the meeting was arranged, the letter which follows (or a minor variant thereof) was faxed to the facility head along with the list of questions in the form shown in this appendix.

STC ENTERPRISES INC.

3290 Cypress Street, Vancouver, B.C. Canada V6J 3N6
Telephone: (604) 736-7656 Burnaby Office: (604) 431-1098
Fax: (604) 431-1128

Date in Feb/March, 1992

(Director of Federal Laboratory)

BY FAX:

re:Study of Federal Research Facilities in British Columbia

Dear Dr. X,

Further to our telephone discussion, I have attached herewith a standard set of questions for which I am seeking replies from all Federal government research facilities in B.C. I thought it might be helpful for you to see this in advance of **our meeting on (day, date) at (time)**.

There are two primary objectives of the study. The first is to provide members of the Premier's Advisory Committee on Science and Technology (PACST) with an overview of the extent of the research conducted by the Federal research facilities and of their impact on B.C. The second is to alert the Committee to any actions which British Columbia might take to augment the benefits to B.C.

The study is small and of short duration. It necessarily relies on any assistance which you and your colleagues can provide in making the information requested available, as well as on suggestions and perceptions which you might have as to what the provincial government or provincial institutions might do to augment the effectiveness of your work.

I am anxious that the study does not cause you undue extra effort, and have tried to request information which I hope, in the normal course of events, will be reasonably accessible to you. As you will see from the questions, they are designed to elicit information on:

1. Mandate and objectives. (2)

2. General background information related to size and staff make-up and their trends over time. (3 & 4)

3. How you measure success, and what your major successes have been in recent years. (5)

4. A set of questions designed to gain an understanding of commercial and academic linkages in B.C. and elsewhere. (6 & 7)

5. An attempt to elicit your suggestions as to what might be done to strengthen linkages in B.C. (8)

6. An attempt to gain an understanding of the economic importance of your activity in terms of the size, growth rate etc. of the industry it supports. (9) (This question will have less relevance for research organizations which are not industry oriented.)

7. Readily available descriptive material concerning your facility (10.1) as well as a listing of key scientific and technical publications. (10.2)

8. Some more detailed information on key projects or categories of projects which will lend concreteness to an understanding of the nature of your activities. (11)

Because it will be necessary for me to try and collate the information received from all the facilities in B.C., it will clearly be helpful if you can provide answers to the questions as given. However, if there are good reasons why the information should be provided in a different form, that will clearly be preferable to not receiving the information at all!

If it should happen that you are having information specially prepared related to these questions, and if that information could also be made available in electronic form (on a floppy disk), that too would be helpful to me.

It is my understanding that PACST intends to make our report of the findings available to interested parties subsequent to its completion, although no formal decision on this issue has yet been taken. Should you wish to contact PACST directly, Mr. Jim Garton, the Executive Director or Mr. Ian Thomas, Administrator, can be contacted in Victoria at 387-9144.

Thank you for your assistance in this undertaking. I look forward to meeting you.

Yours sincerely,

John C. Madden
President

att.

(DEPT. NAME)
(LABORATORY NAME)

1. **Address**

Contact/Title/Telephone/Fax

2. **Mandate/Objectives**

3. **Budgetary Information**

Year	$ Operating	$ Contracts	$ Capital
1988/89			
1989/90			
1990/91			
1991/92			
1992/93			

3.a **Comments (including source of funds):**

4. **Person years**

Year	Research Scientists	Scientific Support	Admin.	Total
1988/89				
1989/90				
1990/91				
1991/92				
1992/93				

4.a **Comments**

5.a **What are your principal criteria for success?**

5.b **What have been or are your most successful projects according to these criteria?**

6. We have been asked to compile statistics to help provide an overview of the spin-offs from federal research activity in B.C. to provincial endeavours in both the private and public sectors. Some of the following questions may not be relevant to your work, but we would be grateful for answers to any that apply.

6.a Do you keep records of patents, published technical papers and citations? If so, could you please provide us with a copy of these lists with comments on any of particular significance?

6.b Have there been any spin-off companies formed in B.C. or elsewhere as a result of R&D performed at this establishment? (We are especially interested in the past five years.)

6.c Have there been any new products produced and sold by B.C. companies, or others, as a result of R&D performed at this establishment? If so, can you estimate actual and/or potential revenues from such sales and the impact on employment?

6.d What intangible benefits to B.C. and elsewhere have arisen as a result of R&D performed at this establishment (e.g. product or environmental improvements, conservation, public awareness)?

6.e Can you point to outstanding research scientists who have been attracted to B.C. as a result of work at this establishment?

6.f Can you point to benefits to provincial R&D establishments, such as universities and colleges, arising from collaborative or other work at this establishment? (Summer student employment should be included as a part of this response.)

7. Which organizations in B.C. and elsewhere are most important to you in terms of collaboration, and which do you view as important role models whose work stands out in your field?

8. Can you suggest any ways that B.C. might derive even more value from the work being carried on at this establishment?

9. Describe the industry or discipline you support. For example, what are the gross provincial (national) revenues for the segment you support; what is its growth rate; how much employment does it generate; what competitive threats does it face; what are the principal challenges (technical and otherwise) faced by the industry? Please include some guiding numbers as to size.

If the principal activity of the establishment is not directly industry oriented, can you provide some indicators of the overall importance of the discipline, and the laboratories' role and status in global activities?

10. Please list the following publications (on separate sheet if desired). If available, and not excessively bulky or expensive, please provide two copies of any useful background documents).

10.a Recent publicly accessible material which describes the activities of your laboratory.

10.b Key scientific or technical papers published by researchers at your laboratory over the past five years.

11. Please list up to ten major projects, or categories of projects, and provide basic information about their objectives, duration, size, significance, and achievements to date. It would also be helpful if you could provide information about their links to other research and potential users in B.C. and elsewhere.

APPENDIX 3

SOME RELEVANT STATISTICAL EXPLANATIONS AND DEFINITIONS

EXPLANATIONS

Almost everyone who has juggled statistics is familiar with the three ascending categories of untruths - lies, damn lies, and statistics. R&D statistics are particularly prone to misrepresentation, and attempts to examine Federal government spending on R&D are even more so. There are good reasons for this.

First there is the problem of definitions. In its very useful analysis of Federal scientific activities entitled *Federal Scientific Activities, 1990-91* (Cat. 88-204) Statistics Canada has provided definitions of *Natural Science and Engineering (NSE), Social Sciences and the Humanities (SSH), Scientific Research and Experimental Development (R&D), and Related Scientific Activities (RSA).*

It is easiest to think of these definitions in hierarchical form as shown in Figure A3.1. The definitions related to Natural Science and Engineering as used by Statistics Canada, as well as the definitions of *Intramural* and *Extramural* spending are reproduced in the next section of this Appendix.

This does not look so difficult - except that in practice, when examining what is transpiring in an individual province or department, it is not uncommon to find that comparisons are being made between NSE figures from one source, but only R&D figures from another. A more important practical difficulty as it relates to this study is that departmental organization in a number of instances stubbornly refused to conform to StatsCan definitions, and actually organized along lines more congruent with departmental objectives!

The line between data gathering which counts as "Related Scientific Activity", and data gathering which is a fundamental part of a scientific investigation can be a slim one, particularly in the marine sciences. The marine science statistics become even further blurred by differing treatment (in our investigations) of the costs of ship time. These are a significant cost factor. In the very limited study reported herein, no serious attempt has been made to differentiate scientific data collection from scientific research and experimental development. However the reader should be able to derive a good sense of the likely proportionate effort in these two activities by examining such figures as

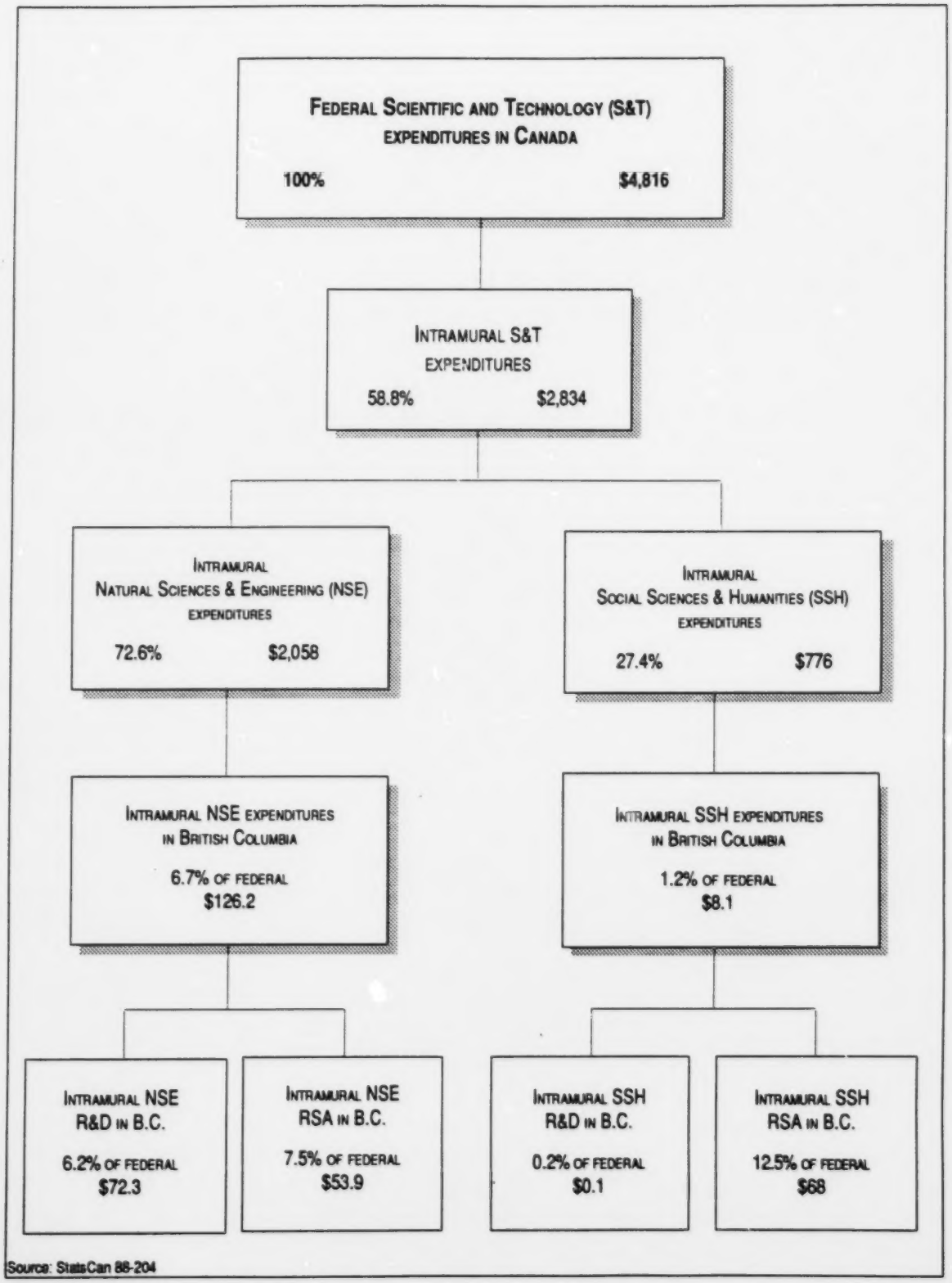

Figure A3.1: Hierarchy of Federal Scientific Activity (FSA) expenditures 1988/89 (in $millions)

the ratio of scientists to technical support staff, as well as from a description of the organization's mandate.

As a part of our data collection activity, we have tried to get some idea of how much research money departments spend with B.C.'s industry and universities. This has been difficult data to accumulate, not so much because departments are trying to withhold the information, as because they don't bother to collect it. Indeed, for some departments, rather than focusing on their contracting out, they were much more focused on the contracts they were able to attract in from industry as revenue sources for their ongoing work. These data are generally provided in the more detailed presentations in Chapters 4 to 10 (where it was made available).

A further important complication of Federal Scientific Activity statistics which has been well handled by Statistics Canada (although not unfortunately to the level of provincial breakouts) relates to the distinction between extramural scientific spending which takes place as a part of *intramural scientific programs*, such as university or industry contracts initiated by an Agriculture Canada research station and paid for out of its own funds, (which for statistical purposes is accounted for as intramural spending), and industry and university research *extramural support programs* such as the various programs of Industry, Science and Technology, Canada (DIST), NSERC and the IRAP program at NRC, which are accounted for as extramural spending.

One major unresolved difficulty we encountered in endeavouring to correlate the data we accumulated with that from Statistics Canada was the substantial difference between our figures for R&D expenditures in B.C. by Forestry Canada and Energy, Mines and Resources Canada and their implied expenditure figures. Our figures were substantially higher. Statistics Canada were contacted concerning this apparent discrepancy. We were told that they too had had difficulty in getting individual expenditure figures by province to correlate with the global departmental expenditures, and had resorted to quoting a global expenditure number, and expressing provincial expenditures as a percentage of the total.

DEFINITIONS

The following definitions are those used by Statistics Canada in analysing and compiling statistical information related to Science and Technology Expenditures. These definitions are extracted from *Federal Scientific Activities, 1990-91*, Catalogue 88-204, pages 53-59.

Scope and Limitations of the Data

The expenditures data for scientific activities controlled by federal departments and agencies correspond to the budgetary expenditures by program presented in Main Estimates for the approval of Parliament. The following kinds of non-budgetary costs or expenditures are not included:

Loans or advances to and investments in Crown Corporations; loans or advances for specific purposes to other governments and international organizations or persons or corporations in the private sector.

Natural Sciences and Engineering

The natural sciences and engineering (NSE) field embraces the disciplines of study concerned with understanding, exploring, developing or utilizing the natural world. Included are the engineering, mathematical, life, and physical sciences.

Scientific Research and Experimental Development (R&D)

Creative work undertaken on a systematic basis in order to increase the stock of scientific and technical knowledge or to discover new applications for existing knowledge. The central characteristic of R&D is an appreciable element of novelty and uncertainty. The work is normally performed by, or under the supervision of, persons with postgraduate degrees in the natural sciences or engineering.

Related Scientific Activities (RSA)

Those activities which complement and extend R&D by contributing to the generation, dissemination, and application of scientific and technological knowledge. These activities include: scientific data collection, information services, testing and standardization, feasibility studies, education support, and museum services.

Social Sciences and Humanities (SSH)

This field embraces all disciplines involved in studying human actions and conditions and the social, economic and institutional mechanisms affecting humans. Included are such disciplines as anthropology, demography, economics, geography, history, languages, literature and linguistics, law, library science, philosophy, political science, psychology, religious studies, social work, sociology, and urban and regional studies.

Intramural Performance

Where science and technology (S&T) activities are managed and carried out primarily by federal government employees they are classified as Intramural S&T. Even where major components of the project are provided by outside agencies (e.g. computer services, laboratory construction, testing of prototype equipment), if the planning, supervision, reporting, and key operating functions are performed by federal personnel, then the activity is considered to be intramural. This also applies to S&T activities carried out by a department or agency on behalf of another federal department or agency on a cost recovery basis.

The intramural expenditures reported for scientific activities are those direct costs, including salaries, associated with scientific programs. These costs include that portion of a program's contribution to employee benefit plans (e.g. superannuation) which is applicable to the scientific personnel within the program. Non-program ("indirect") costs, such as the value of services provided by other departments without charge and accommodation provided by the reporting program, are also included.

Extramural Performance

The management and conduct of an S&T activity is entrusted to a non-federal organization. The six extramural performance sectors used in surveying S&T expenditures by the Federal Government are: Canadian industry, Canadian universities, Canadian non-profit institutions, Canadian provincial and municipal governments, other Canadian performers, and foreign performers.